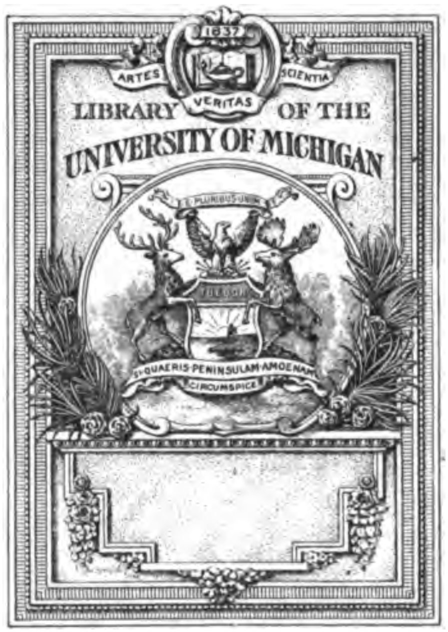
MISSOURI

GEOLOGICAL SURVEY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MISSOURI

GEOLOGICAL SURVEY

VOLUME XI

CLAY DEPOSITS

BY

H. A. WHEELER

CHARLES R. KEYES

STATE GEOLOGIST

JEFFERSON CITY

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LETTER OF TRANSMITTAL

MISSOURI GEOLOGICAL SURVEY,
JEFFERSON CITY, Nov. 15, 1896.

To the President, Governor Wm. J. Stone, and the Members of the Board of Managers of the Bureau of Geology and Mines:

GENTLEMEN: I have the honor and pleasure to transmit to you the report on the Clay Deposits of Missouri by Prof. H. A. Wheeler, E. M.

The importance of the industry may be judged, when it is recognized that the annual production is valued at nearly $7,000,000. No part of the State's natural resources has been perhaps less appreciated. This neglected industry was therefore one of the first to secure the attention of the Geological Survey after its establishment.

In the beginning, the investigation was intrusted to Mr. George E. Ladd, who spent the greater part of the season of 1890 in the field, making detailed studies and collecting samples. In this he was assisted by Mr. E. H. Lonsdale. Early in the same season Prof. H. A. Wheeler was appointed to investigate the physical and chemical properties of the material collected by Mr. Ladd. Thirty-three samples of clays and shales were studied this year, the chemical analyses of which were made by Mr. A. E. Woodward, the chemist to the Survey.

In 1891 active work in the field was continued by Mr. Ladd, until his resignation in the latter part of the summer. He collected 58 additional samples of clays and shales which were also examined by Professor Wheeler, the chemical analyses being made at the St. Louis Sampling and Testing Works.

In 1892, Professor Wheeler was given charge of the entire work, undertaking both the field investigations and the physical tests. Mr. Leo Gluck, E. M., was detailed to assist in the field, office and laboratory work, in which capacity he served for about one year. During this season Mr. Gluck spent five months in reconnoissance work, and Professor Wheeler about three months on special work. Fifty-two samples were obtained, which were worked up during the following winter.

The field work was continued in 1893, for about four months, by Professor Wheeler, the rest of the year being devoted to completing the investigation of 25 different samples. The analyses of these were undertaken by Mr. J. D. Robertson, E. M., at that time acting chemist to the survey. A critical study was made of the results of the physical and chemical examinations of the 168 samples of clays and shales which had been obtained since the inauguration of the work. During the latter part of the same year arrangements were made with Dr. Erasmus Haworth to conduct a microscopical investigation of certain samples of clay in the hope that the microscope would furnish conclusive evidence in regard to certain physical properties. Doctor Haworth submitted the results of his studies, from which extracts and some illustrations have been incorporated in the report.

The preparation of the manuscript of the report on the clays was begun in January, 1894. This Professor Wheeler carried on at such opportunities as were permissible, during his occupancy of an active chair in Washington University.

I remain, with great respect,

Your obedient servant,

CHARLES R. KEYES.

State Geologist.

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PREFACE

The number, extent and importance of the industries based upon clays has been little realized, not only by the people of Missouri, but also by those living beyond the limits of the state. Still less has the existence, distribution and qualities of the available deposits been comprehended. Yet, today the manufacture of clay products constitutes one of the leading features in the industrial activities of the commonwealth. The capital invested in the clay industries of the state at the present time amounts to nearly $7,000,000.00; and the value of the annual product is considerably more.

As Missouri contains 114 counties, comprising an area of 67,380 square miles, and as every county contains clay deposits of greater or less magnitude and value, it was not possible, with the amount of time and means given to the subject, to thoroughly study every occurrence in such an extensive area. It was therefore necessary to discriminate somewhat in favor of those districts that were already available to the market, as well as to those which promised to become so on account of the quality of the clay or from commercial conditions. Districts which did not enjoy these advantages were either only hastily inspected, or not personally visited, so that much necessarily remains to be done in the future, to give a complete description of the resources of the entire state. The very important brick and fire-clay deposits of the St. Louis district, the potter's clay deposits of Henry county, and the china and kaolin deposits of the southeastern portion of the state, which are active shipping districts, have been carefully studied and much valuable information is placed on record. The valuable and numerous flint-clay deposits of the central portion of the state have been thoroughly investigated. They show a remarkable purity in composition, although the individual deposits are rather limited. The kaolin deposits in the southern portion of the state have been sufficiently described to show possible future of this district, after the clays have been washed, which most of the kaolin is unmarketable.

eat loess deposits, on the Mississippi and Missouri rivers, o extensively worked at St. Louis, Kansas City and St.

Joseph, have been treated with sufficient breadth to show the unlimited quantity and high value of this material for brick-making. The hitherto much neglected and unappreciated deposits of shale have been given much attention, on account of the wide field in which they may be employed. The shales are so abundant in the northern half of the state and vary so greatly in quality, while their field of application is so broad, that they alone are entitled to more time than has been devoted to the entire report. The very extensive glacial clays that cover the northern half of the state have only been lightly touched upon; for although they are liable to contain local pockets of workable clays, they are so variable in quantity, and so uncertain in quality and in most cases they are so unsatisfactory economically, as to make it necessary to subordinate them to the more valuable clays that usually occur underneath. The gumbo clays, which are proving so valuable in the burning of ballast for railroads, have only been treated in a broad, general way; for they are too extensive to be thoroughly investigated in a limited time.

The statistics of the clay industries of Missouri nave never been collected before. They are only approximately correct, as it has been necessary to estimate the output of many of the small brickyards and potteries.

As it is often desirable to have the analyses of well known clays for purposes of comparison a very complete list of analyses of American and foreign clays has been compiled. They were selected with reference to their importance and presumed reliability.

A brief working bibliography has been added, in which only the most accessible and standard works have been cited. While there are many references to articles in foreign periodicals that could have been added they are so difficult to get, that they have been omitted.

In the prosecution of the work acknowledgements are due: Mr. Arthur Winslow, for the deep interest taken and valuable suggestions given while he was state geologist; Prof. Wm. B. Potter, for valuable criticism; Mr. Leo Gluck, E. M., for his warm interest and zeal in carrying on the tests in the physical laboratory; Mr. James D. Robertson, E. M., for valuable aid and suggestions in the preparation of the manuscript; Prof. E. Haworth, for the deep interest and zeal he has taken in the microscopic study of the clays; Dr. J. H. Britts, for the valuable information furnished concerning the Henry county district, with which he is so thorough acquainted both commercially and geologically; Prof. E. M. Shepard, of Springfield, and Maj. E. W. Newton, of Bolivar, for the information regarding Greene and Polk counties. Also to Dr. G. Hambach and Prof. J. B. Johnson, of Washington University,

Prof. W. H. Seamon, now of Soccoro, New Mexico, Prof. Arthur Thatcher, Wm. Chauvenet, and J. B. Clements, of St. Louis, Messrs. Emerson L. Foote, of Sligo, D. K. Greger, of Fulton, Julian Bagby, of New Haven, J. W. Barney, of Kansas City, Wm. Sankey, of Salem, and Prof. Heinrich Ries, of Columbia College, New York.

Besides those to whom the Survey is under special obligation there are many others, almost too numerous to mention, who have given aid in one way or another, and especially in the field; to all these grateful acknowledgement is tendered.

H. A. W.

CLAYS OF MISSOURI.

BY H. A. WHEELER, E. M.

CHAPTER I.

INTRODUCTORY.

Definition of Clay. The scientific definition of the term clay is: a more or less pure variety of the mineral kaolinite, the hydrous silicate of alumina. The popular definition of clay is: an earthy material that becomes plastic when mixed with water. To the laymen and the clay-worker, plasticity is primarily the predominant characteristic of all clays, and the other properties that are associated with plasticity give rise to the different varieties and uses. If the very important property of plasticity is required as an essential feature of clay, as this is the property that gives clay its sole advantage over all other minerals for the purposes to which it is applied, then the scientific definition is faulty, as some of the purest varieties of kaolinite are lacking in plasticity. Although the popular definition does not apply to any other mineral in actual use beyond that covered by the scientific term, yet there are other minerals which may be rendered plastic and consequently should come under this term, though they contain no kaolinite and are very different from that mineral in all other properties.

While the popular definition appears to be sufficiently broad and accurate for all practical purposes, that a clay is an earthy substance that can be rendered plastic when mixed with water, the scientific definition more sharply brings out the fact that the term clay can only be defined in a broad general way, as there is a want of sharpness of demarkation between plastic and non-plastic substances. One of the purest forms of kaolinite known occurs in extensive beds in Missouri and most frequently it is in a non-plastic condition; yet these very deposits of non-plastic clay (the flint clays) not infrequently are found more or less plastic at the outcrop. In other words there is in a

single bed a transition of the same substance from a non-plastic to a plastic condition; yet in each instance it is an exceptionally pure variety of kaolinite or an almost pure hydrous silicate of alumina. The purest specimens of the crystalized mineral kaolinite are almost always lacking in plasticity, though they can be rendered plastic by fine grinding. It is therefore evident that the exclusive recognition of the property of plasticity would bar out some of the most important clay deposits of Missouri, so that this predominating factor cannot be safely used as the sole distinction in defining a clay.

The chemical composition cannot be exclusively used. The non-plastic flint clays would then immediately come within a chemical definition: that clays consist essentially of hydrous silicate of alumina; and there are clays which not only come within the term plastic earths, but are used by clay-workers for making brick, tile, and other products, yet they consist mainly of other substances than kaolinite, or the latter is of minor importance in a complex mixture. The range in the chemical composition of commercial clays is found to vary from pure kaolinite on one side, to earthy masses in which the mineral kaolinite almost completely disappears. There is thus a complete transition in the composition from pure kaolinite to argillaceous moulding sands, and from non-plastic to extremely plastic varieties. A safe and broad definition which recognizes this marked variation in plasticity, and the great range in composition, and which is essentially based on silicate of alumina would be: "Clay is an earthy mineral that possesses more or less plasticity, and in which hydrous silicate of alumina is the dominating constituent."

Base of Clays. The mineral that is usually regarded as the source of plasticity in all clays is kaolinite, of which kaolin or china clay is supposed to be a pure variety. The composition of kaolinite as given by Dana is as follows:

	Per cent.
Silica	46 36
Alumina	39 73
Combined water	13.91
Total	100.00

This gives the formula $Al_2O_3, 2SiO_2+2H_2O$; or it is a hydrous silicate of alumina in which there is a chemical combination between the water and the silicate of alumina. Kaolinite crystalizes usually as thin white scales; it has a hardness of 2.5, and a specific gravity of 2.4 to 2.6. It very seldom occurs in thin plates. In this form it is of no economic value, as it is rare even in mineralogical museums. It possesses no plasticity and hence it appears to lack the vital property of clay. If the plates or crystals are ground very fine the powder becomes more

or less plastic, and the finer it is ground, the more plastic it becomes; hence, it would seem that this mineral renders clays most plastic when proper mechanical conditions have broken up the coarse plates into a minute scaly condition. The usual condition of the mineral kaolinite, as it is found in large bodies of great commercial importance, as in the beds of china clay, fire clay and potters' clay, is a plastic, more or less pure hydrous silicate of alumina with which is associated certain impurities that are nearly always present, though in very variable amounts.

A mineral that is rarely absent and that is usually present to a marked extent is the sand, or free silica. Another mineral that is seldom absent and occasionally is present to a notable degree, though rarely as abundant as the sand, is feldspar. In the purer kinds of clay they are the two minerals which, with the kaolinite, make up from 80 to 95 per cent of the complex mixture that is termed clay. They are liable to fluctuate between the following limits:

	Extreme Limits.	Usual Averages.
Kaolinite	15 to 95 per cent.	40 to 75 per cent.
Sand	5 to 60 "	20 to 40 "
Feldspar	3 to 35 "	5 to 20 "

Associated with the three minerals there usually occurs in variable amounts, according to the mode of origin of the clay, carbonate of lime, carbonate of magnesia, carbonate of iron, pyrite, oxide of iron, mica and gypsum. A discussion of the form and the amount of these associated minerals is fully given in the chapter on the chemistry of clay. It is evident, then, that clay consists of a more or less complex mixture of kaolinite and several other minerals which, to the unaided eye, are in a massive or earthy condition. Sometimes these different minerals are blended into a homogeneous mixture in which none of the constituents can be discerned. More frequently from variation in the size of the grains of the different minerals, or lack of uniformity in the mixture, one or more of the minerals can be detected by the eye, especially if aided with a pocket lens. Sand, pyrite, mica, selenite and feldspar are to be seen as more or less coarse-grained crystals disseminated through a fine groundmass.

Definition of Shale. A shale is nothing more than an eminently stratified clay in a more or less hardened or indurated condition. The stratification shows that it was deposited by water in motion, and hence the shales are likely to be impure, as they are liable to be contaminated with sediments of any nature that may have been carried by the currents. Shale sediments have accumulated so rapidly that they have not been subjected to the purifying action of the prolonged leach-

ing as the flint clays have in their very slow rate of accumulation in sink-holes; nor have they had the benefit of the purification by the extracting action of the roots of plants that the many fireclays have enjoyed in accumulating in swamps; neither have they had the benefit of the prolonged solvent action of surface waters as in the case of the kaolins *in situ*. They are, as a class, usually the most impure of all clays and this is the reason that they are so well adapted for vitrified brick. They are identical with the clays in their general chemical properties, and their dominating constituent is kaolinite.

Physically the shales differ from the clays only in being usually rather harder and more rock-like and in requiring reduction to a powder before being worked with water into a plastic mass. This latter feature results from the great pressure to which they have usually been exposed by the weight of overlying masses which have produced the indurating action. The misleading terms "argillaceous shale" and "clay-shale" are simply indicative of a soft, less indurated condition of the shale, rather than the fact that they are any purer or richer in kaolinite than hard or lean shales. When the pressure of the overlying masses has been very great, or where there has been chemical action resulting from heat or pressure, the clay not only becomes eminently lamellar but it is rendered much harder and stronger, and it no longer becomes plastic when ground to a powder. It is then known as slate. A slate is, therefore, a metamorphosed shale in which the chemically combined water is more or less completely expelled and in which the property of plasticity is destroyed.

Hence, when the term clay is employed no distinction is implied between the softer, usually less eminently lamellar earthy matter that is popularly called clay, and the harder, usually well laminated material that is called shale.

ORIGIN OF CLAYS.

Primarily all the clays are derived from the chemical decomposition of igneous rocks. The teachings of geology show that these are the oldest rocks known in the history of the earth. Subsequently clays have been derived by either the mechanical or chemical disintegration of the sedimentary rocks or the shales, slates, limestones, and impure sandstones, as well as the altered varieties of these rocks that are known as the metamorphic series; but all the sedimentary and metamorphic rocks were primarily derived from the igneous rocks. The possible sources of clay are therefore very great, as practically all rocks are liable to produce greater or less quantities of more or less pure clay, when broken up by chemical decomposition or mechan-

ical disintegration, but in all cases the primary derivation is the same whether the igneous rocks belong to the old or plutonic series, as granite and syenite, or to the very recent volcanic series, as lava, basalt and trachyte.

The igneous rocks consist of one or more members of the feldspathic group of minerals which always make up a larger proportion of these rocks. With the feldspar is associated one or more of the following minerals: quartz, hornblende, augite, mica, and in unimportant amounts a few other minerals that are mostly silicates. The feldspars are silicates of alumina, lime, soda or potash. The hornblendes consist of the silicate and alumnate of lime, magnesia and iron. The micas are complex silicates of lime, magnesia, iron, potash and soda.

Chemical decomposition known as kaolinization takes place when these silicates of alumina and other bases are exposed to air and moisture, when a complete breaking up of the molecules takes place, resulting in the production of kaolinite, or the hydrous silicate of alumina, the separation of the free silica, or quartz, the conversion of the lime, iron and magnesia into carbonates that are carried away through the waters, and the removal of the alkalies as sulphates and chlorides which pass away in surface waters. The hard, tough, apparently resistant granites and basalts, which are the strongest and most durable of building stones, are all found to yield with more or less readiness to the continued solvent action of combined air and water. The surface waters, with an apparently insignificant charge of dissolved oxygen and carbonic acid, especially when points of attack are increased through the mechanical disrupting action of frost, will eventually soften, destroy, and completely decompose these rocks. Some of them yield very much more slowly than others, as is notably the case of the albitic granites; but in time they are all affected and yield to the action of meteoric agencies. When the rainfall is great the disintegrated material is usually removed as rapidly as it is produced by chemical decay, so that in those places in which the granites are often exposed at the surface the combined action of frost and rain removes the soft, decayed part or clay and sand almost as rapidly as it is produced. In the regions of limited rainfall the decay of the igneous rocks proceeds more rapidly than their removal by erosion. They are found to be soft and to be converted into clay and sand for a distance of 100 to 1500 feet below the surface, or until the permanent water-level is reached. When the igneous rocks are beyond the reach of air, or below the permanent water-level, the yare no longer effected, as water without air appears not to have such a powerful decaying action.

When these rocks have rotted into the soft condition of clay, they become very amenable to erosion and are washed into the streams as a fine sediment which is subsequently deposited as mud in the lakes, estuaries and seas. The coarser particles of the decayed rock usually consist of the quartz, which is deposited as sand and gravel, and eventually converted into sandstone and conglomerate. The finer sediments are deposited in quiet waters as silts and muds, which later are converted into clays, shales and slates. The dissolved substances, as iron, lime, magnesia and alkalies, are carried into the lakes and oceans where they become precipitated, under favorable conditions by organic or chemical agencies, as deep-sea ooze, iron mud and rock salt, which afterwards are converted into limestone, iron ore and salt beds. When these sedimentary products, which were derived from the chemical decomposition of the igneous rocks and afterwards removed by streams to their places of deposition become subsequently elevated above the level of the lakes and oceans in which they were formed and become the land surfaces, they suffer the same chemical and mechanical disintegration, removal, transportation and redeposition as beds of sands, muds and calcareous ooze, as previously happened to the igneous rocks. If before the re-elevation of the sedimentary beds they are exposed to suitable conditions of heat, pressure and chemical action as to modify the form and constitution, the metamorphic rocks result, but they are subject to the same law of decay when exposed to air and moisture, and they similarly yield and pass through the same cycles as the igneous or sedimentary rocks, though at a less rapid rate.

This briefly is the origin of all rocks since the decomposition of the primary igneous rocks and, as the cycle is being constantly repeated, it results in the broad distinction of three classes of sedimentary deposits; the coarse sand deposits that produce the sandstones, the fine earthy deposits that form the clays and shales, and the deep sea ooze or the calcareous deposits which finally produce the limestones and dolomites. It is the fine earthy deposits, or clays to which particular attention is called; and it is necessary to examine more closely into the mode of origin to appreciate the marked variations that are found in the character of the different clay beds. As just shown, clay is not an original product of the earth's crust, but is a secondary material resulting from the decay of other rocks. The kind of rock from which it has been derived, the thoroughness of the decomposition, the mode in which the deposit was formed and the length of time in forming, account for the great variations that are found in the purity, character and thickness of the differ-

ent deposits. The purity of clay derived from granite, *in situ*, depends upon the constituents in the original granite; its physical and chemical characters upon the thoroughness with which the decomposition has progressed; and the thickness of the deposit upon the length of time or slowness of the erosion and removal of the decayed granite. If the granite consists of only orthoclase feldspar and quartz, with no iron-bearing minerals, and the decomposition has been thorough, there remains behind a soft, white, pulverent mixture of kaolin and quartz. Such a deposit furnishes the purest quality of kaolinite, or china clay, when freed from mechanical admixed quartz or sand, by simple washing, by which the fine clay particles are easily separated from the coarse heavy sand particles. Should the granite contain iron minerals as limonite, magnetite and pyrite, which remain in the more or less altered condition of limonite, a yellow to brown color is imparted to the clay. If the granite contains hornblende or mica, and the lime, magnesia and iron are not entirely removed, the fusibility of the clay is materially increased. As the great majority of igneous rocks contain iron minerals the derived clay is usually very thoroughly and completely impregnated by the yellow to brown hydrous sesquioxide of iron, or limonite. If the ferruginous clay is removed by erosion and is deposited on the shore of a lake or estuary where animal and vegetable life exists, the iron is reduced to the protoxide condition, giving the clay a blue or green to black color. If the clayey material is deposited in a swamp where there is a luxuriant growth of vegetable matter, the alkalies, the iron, the lime and the magnesia are more or less completely extracted from the clay by the plants and rendered so pure as to be refractory. This is the source of most of the beds of true fireclay.

As there are many different kinds of igneous rocks, as granite, syenite, quartz-porphyry, gabbro, diabase, dolerite, trachyte, rhyolite and andesite, there is commonly a great variation in the resulting clays, according to the rock from which they have been derived and the completeness with which the decomposition has been effected. As chemical action or decay proceeds from the surface inward, at every joint-plane, crack or seam, it is seldom that the entire rock mass is completely decomposed. More or less imperfectly decomposed portions of the original rock remain in the clay and these fine particles of the original rock are not only found intermixed where the clay occurs, *in situ*, but also where it is transported and redeposited. This same remark applies to clays that are derived from the so-called metamorphic rocks, which are transitions in their physical and chemical properties between the igneous rocks on the one side and the sedimentary rocks

on the other. A feature that is often overlooked is that such sedimentary rocks as sandstones and limestones, when decomposed through mechanical and chemical action, produce more or less clay. There is scarcely a sandstone that does not contain clay, and there are very few limestones that do not likewise contain some argillaceous matter. In the mechanical disintegration of the sandstone or the chemical decomposition of the limestone the clay is set free either to accumulate on top of the formation as residual clay, or to be borne away and redeposited as silt.

A very important fact connected with the origin of clay, and one which has great influence upon the plasticity, is that the farther clayey material is transported during which it is constantly exposed to the abrading and comminuting action of the particles upon themselves as well as upon the banks and bottoms of streams over which they are carried, the finer they are ground and the smaller are the scales into which the kaolinite particles are broken. The smaller the crystalline plates of kaolinite are divided the more plastic is the clay, so that those clays that have been subjected to severe wearing action are likely to be extremely plastic, whereas those that have had little or no wear, as those formed *in situ*, are but slightly plastic. This is well shown in the glacial and loess clays, where the mechanical disintegration and abrasion of the clay particles has been great. Such clays are very plastic, though possessing a very moderate amount of kaolinite; while many of the china and flint clays which have not been transported possess almost no plasticity.

CLASSIFICATION OF CLAYS.

Attempts to classify clays are far from satisfactory as there are transitions in the physical properties and chemical composition from the purest porcelain clay, at one end, to the most inferior grade of gumbo clay at the other. While the difference is most marked and sharp between the two widely separated types the intermediate clays present a complete series that graduates from the one extreme to the other preventing the drawing of rigid lines. In most cases certain types of clay are found to have persistent properties which render them especially desirable for certain applications. As the commercial world draws the lines rather sharply, and as it is desirable to clearly bring out the prominent characteristics for the demands of each department of ceramic ware, a more or less arbitrary classification must be made. Although such an arrangement is of great convenience it is at best imperfect, for the intermediate or transition clays must be placed under two or more heads. The classification which appears to

be the most convenient and least objectionable, in which the purpose for which each clay is to be used is the basis, is as follows:

1.	White ware	Kaolin. China clay. Ball clay.
2.	Refractory	Plastic fireclay. Flint clay. Refractory shale.
3.	Potters'	Plastic clay and shale of moderate fusibility.
4.	Vitrifying	Paving-brick clay and shale. Sewer-pipe clay and shale. Roofing tile clay and shale.
5.	Brick	Common brick clay and shale. Terra cotta clay and shale. Draintile clay and shale.
6.	Gumbo	Burnt ballast clay.
7.	Slip	Clays of very easy fusibility.

1. In the first, or white-ware class, are clays which are so free from iron as to be suitable for the manufacture of porcelain, china, ironstone ware, encaustic tiles, "C. C." ware, or the highest grades of ceramic ware. Those grades suitable for these purposes are the scarcest and highest priced. They are not necessarily the richest or purest in the kaolinite base, as they contain a considerable amount of sand and feldspar, and often assay high in silica and moderately high in lime, magnesia and the alkalies. They are always very low in iron, and are moderately to decidedly refractory. The high price results from their scarcity; hence they can only be used for high grade goods, especially the plastic bond-clay which is very desirable for other purposes if the question of cost were not prohibitory. A good bond-clay is well adapted for fire-brick, buff and ornamental brick, terra cotta, draintile, stoneware and earthenware, but the value is too great for applications where cheaper clays can be employed. The sole question that decides as to whether it is a bond-clay, fireclay, potters' clay, or terra cotta clay is the question of a greater or less quantity of iron. The percentage of iron in white-ware clays ranges from 0.3 to 2.0, but it is usually less than 1, while the total amount of fluxing impurities ranges from 1.5 to 4.0 per cent. The clays are commonly white or very light in color, though occasionally dark from the presence of organic matter. As the latter is expelled in burning, leaving a white body, it is not harmful. They vary from a light, pulverent, slightly plastic and lean, as in some of the kaolins, to compact, hard, tough and very plastic, as in the bond variety.

2. The second, or refractory, group embraces those clays which are sufficiently free from fluxing constituents as to be able to resist the high heat that is necessary in the uses to which fire-brick are put. In these clays the percentage of iron, lime, magnesia, and the alkalies must be low. The total amount of these fluxing impurities usually ranges from 2 to 7 per cent. The fireclays consist mainly of kaolinite

and more or less sand; the other foreign matter being a small amount of feldspar and a little pyrite or oxide of iron. Refractory clays may be highly plastic and easily moulded, as is usually the case with those which occur under beds of coal; or they may be non-plastic, as in the flint clays.

The term fireclay has been grossly abused, by applying it to all clay seams upon which rest the coal beds. While such beds of clay generally have a characteristic appearance, and strongly resemble one another, they vary greatly in their purity and therefore in their fusibility, and the majority of them are not refractory enough for the manufacture of fire-brick. A true fireclay should withstand, without melting, a temperature of at least 2500°F., which is a white heat. A few shales that are decidedly above the average in purity are sufficiently refractory to answer for fire-brick, but such fire-shales are exceptional. The refractory clays and shales vary from white or light gray to dark gray or almost black, with occasional yellow or brown iron stains or streaks. The dark coloring matter is of organic origin and burns out on heating. There is usually sufficient iron present to give the ware a spotted or mottled appearance after burning when the iron fuses into small black or brown spots of slag.

3. The third class includes those potters' clays and shales, which are not refractory enough for the making of fire-brick, yet are sufficiently free from iron to burn to a light-colored body. They merge into the fireclays on one side, which latter are not infrequently used for stoneware, and into the vitrifying and paving brick clays on the other. In most cases they have a well-marked plasticity and are moderately free from iron, but they are often high in lime, magnesia, and the alkalies, which renders them more or less fusible. They range from 1.5 to 4.0 per cent in iron, while the total fluxing impurities vary from 3.5 to 9.0 per cent. A few shales are suitable for this purpose, though more frequently the potters' clays, in Missouri at least, are either found underlying the coal seams or occur as beds and pockets in the more recent formations. They vary greatly in color, being various shades of olive green, purple, red, yellow and brown, and occasionally very dark or even black, from the presence of organic matter. They are usually washed before use to free them from iron and coarse impurities.

4. The fourth, or vitrifying class, comprises very impure clays and shales that are so high in fluxing impurities as to readily vitrify, with the production of a strong body. Such varieties have generally a high percentage of iron and the alkalies, and vary from 8.0 to 16.0 per cent in fluxing impurities. The high percentage of the latter ren-

ders them fusible. If the fluxing material consist mainly of iron and the alkalies, with suitable physical properties, the clay upon heating very gradually attains the point of vitrification, and then passes beyond to the yielding stage. This is the critical distinction between the vitrifying and the brick clays, as the latter are likely to be equally impure. The very impure composition is more frequently found in the shales than in the clays and the majority of the former that can be rendered plastic when ground belong to this class.

5. The fifth class includes the very impure clays and shales suitable for common brick, terra cotta, draintile, flower-pots, and other coarse earthenware. The amount and character of the fluxing impurities are such that they cannot be safely vitrified without heavy loss. They are not usually as impure as those of the previous group. Being as a rule high in lime and magnesia, the clay passes suddenly into fusion, and hence it cannot be used for paving-brick and sewer-pipe. The total amount of fluxing impurities in these clays ranges from 8.0 to 12.0 per cent and occasionally even much higher. They are usually yellow to brown in color, though occasionally green or purple to red, rarely dark-colored on account of organic matter.

6. The gumbo clays are those peculiar varieties that are admirably adapted for burnt ballast, but which are valueless for any other purpose as they crack to pieces in burning. They are as impure as the vitrifying clays, and their peculiar property of cracking up into gravel when burned is a physical question rather than a chemical one. The total amount of fluxing impurities ranges from 10.0 to 14.0 per cent.

7. The seventh class, or slip clays, takes in all those extremely impure clays that are so high in fluxing impurities as to very readily and quietly pass into fusion upon heating. They are usually very high in iron, and not infrequently contain manganese, which is a very powerful flux. They range from 14.0 to 20.0 per cent in fluxing impurities, and are deep colored from the excessive amount of iron.

All these different clays are found within the limits of Missouri. The details of their character and occurrence are later given. It will be noticed that the preceding classification is mainly based on the chemical composition. As will be shown in the chapter on chemical properties of clays, the question of fusibility is very largely influenced by the form of combination, as well as the amount of the fluxing constituents, the specific gravity of the clay, and the fineness of grain, all of which features are ignored in this classification. If allowance is made for these physical factors the preceding chemical classification becomes more sharply defined as well as reliable and convenient.

ECONOMIC IMPORTANCE OF THE MISSOURI CLAYS.

The economic importance of the different clays of Missouri varies greatly, both in quality and quantity, as is well shown in the subsequent summary of the annual output and value of the different grades.

Glass Pot Clay is the most valuable that is found in the state. The superior quality that is found in the St. Louis district is worth from $10.00 to $14.00 a ton for the No. 1 grade of crude, picked and washed potclay, and $4.00 to $6.00 a ton for the No. 2 grade. Although the St. Louis fireclay seam in which this very valuable potclay occurs covers about 180 square miles, or nearly one-half of the county, this exceptionally pure grade of clay is only found in local pockets or basins in this seam. Thus far only six such pockets have been found, all of which are limited in size and two are already exhausted. About 16,000 tons of this high grade clay are produced annually, mostly of the washed variety.

Ball Clays rank next in value, as they are worth from $6.00 to $8.00 a ton for the No. 1 grade, and $3.00 to $5.00 a ton for the No. 2 grade. Only a few pockets of this valuable clay have been found as yet in Missouri. They are all in the eastern central portion of the state, and mainly in Jefferson county. They occupy local disconnected basins or pockets in limestone, and are very limited in extent. When exhausted they leave no clew as to the whereabouts of other deposits. The pockets at present known are nearly exhausted, and active prospecting is necessary to uncover new ones. Other deposits undoubtedly exist and moderate amounts of this kind of clay are likely to be produced for a considerable time. At present the annual output does not exceed 1,500 tons.

Kaolins have thus far been produced in but small amounts, and these from the southeastern portion of the state. Carelessness in sorting has greatly injured the reputation of the Missouri kaolin, so that it is not popular among the white-ware potters. If washers are erected a much superior quality can be guaranteed and a large business can be won when the trade can rely on the uniformity of the product. When this is done very large amounts of mixed kaolin, sand and flint that are now left on the dumps as waste, can be saved and converted into a high grade article. This will greatly stimulate production so that the future of this district is still ahead. While the deposits are all local, disconnected pockets occupying basins in the limestone, they are very numerous. An output could be maintained for many years, that would supply the entire Western demand for this class of china clay. At present only about 1,000 tons a year are produced.

Flint Fireclays rank next in value, as they formerly sold for $2.00 to $3.00 a ton on board the cars at the mines. Keen competition has so lowered the price that $1.00 is now the standard and some sales have been made as low as 75 cents a ton. They invariably occur in local pockets or old sink-holes in limestone, and hence are soon exhausted; but the pockets are so numerous particularly in the east-central portion of the state, that the present annual output of about 12,000 tons could be heavily increased, and maintained at the higher figures for many years.

Plastic Fireclays that are suitable for refactory purposes are very abundant at the base of the coal measures in the east-central portion of the state, and are probably not of infrequent occurrence in the southwestern portion, but of less satisfactory quality. The eastern district is scarcely opened. Not only could its present annual output of about 200,000 tons to be greatly increased, to at least 2,000,000 tons annually, but could be maintained for a very long time. The usual price for this class of clay is $1.00 a ton on board the cars at the mines, though selected lots bring $2.00 to $4.00, and common grades as low as 75 cents.

Stoneware Clays are scarcely touched at present. In the limited output of about 10,000 tons a year that is taken by the small Missouri potteries, it is difficult to estimate how much larger the product could be increased without affecting the source of supply. The western portion of the state could meet a heavy demand for an indefinite period, while the eastern portion could probably at least equal, if not exceed such future large demand, should Missouri potteries ever require it. This class of clays is of low value, usually commanding not more than 75 cents a ton on board the cars at the mines.

Inferior clays that are used for terra cotta, sewer pipe, tile and flower-pots are the impure fireclays, potters' clays and shales. They occur in very large quantities throughout the northern and western portions of the state, and to a large extent in the St. Louis district and immediate neighborhood. The state could enormously increase the present annual output of about 170,000 tons, and maintain such enlarged production for an indefinite period, as the demand arises. Such clays are low-priced, from 25 to 75 cents a ton on board cars, according to the quality, size of deposit and conveniences for shipping.

Paving-brick shales have only begun to be used. The northern half of Missouri can furnish inexhaustable supplies of shale of good quality from its numerous beds that are frequently of great thickness. The value of this class of clay is small, as it is usually worth from 20

to 50 cents a ton, or about the cost of getting out at present. About 110,000 tons a year are mined.

Building Brick Clays are simply inexhaustible in Missouri, and of the very best quality. The loess furnishes a clay of exceptional uniformity and value for this purpose. As the loess deposits flank all the large rivers of the northern half of the state, and especially the Missouri and the Mississippi, along which it is from 15 to 100 feet thick, and extends 5 to 10 miles from the river, future generations will be able to draw indefinitely on such an exhaustless body of this excellent material. The resorted residual and glacial clays that are also used to a small extent for building brick are usually limited in thickness and amount; but they cover such wide areas, the former in the southern half and the latter in the northern half of the state, that local brickyards will have ample sources of supply for an indefinite future. This class of clays is the lowest priced of all, being worth from 10 to 20 cents a ton, or about the cost of mining. About 1,300,000 tons a year are used.

Gumbo Clays are exhaustless in Missouri, as they occupy such extensive areas along the floodplains of the larger rivers. At present it does not pay to work them to a greater depth than 8 or 10 feet on account of water, but even with this shallow cut the railroads can draw indefinitely on the present known deposits. These clays are worth only the cost of digging, or from 5 to 10 cents a ton. One million tons a year are used.

Summary. The present output and value of all the clays in Missouri as here given is only approximate. In many cases no records whatever are kept by the persons engaged in the work and in others very imperfect ones, so that this statement is more valuable as a general guide than for its absolute intrinsic merit.

Amount and Value of Annual Clay Output.

KIND.	AMOUNT—TONS.	VALUE.	WHERE USED.
Kaolin	1,000	$4,000	Shipped east.
Ball clay	1,500	9,750	Shipped east.
Glass-pot clay	16,000	160,000	4-5 shipped, 1-5 in state.
Flint fireclay	12,000	12,000	¼ shipped, ¾ in state.
Plastic fireclay	209 000	209 000	1-10 shipped, 9-10 in state.
Stoneware clay	10,000	7,500	1-10 shipped, 9-10 in state.
Terra cotta, tiles, sewer-pipe, etc	168,000	113,500	In state
Paving brick shale	108,000	27,000	In state.
Building brick clay	1,300,000	260,000	In state
Gumbo, for R. R. ballast	1,000,000	100,000	In state.
Totals	2,825,000	$900,250	

ECONOMIC IMPORTANCE OF THE CLAY INDUSTRIES.

Building Brick. The most important clay industry in Missouri is the manufacture of building brick, which exceeds in number and value all the other clay industries combined. There are 358 brickyards, with an estimated capital of $3,434,000, that produce about $3,500,000 worth of brick annually. One company alone has a capital of $3,000,000, and operate ten large yards in the state, that have a producing capacity of 155,000,000 brick, of which one-third are stock or ornamental grades. This large industry is founded on the extensive deposits of the loess. Not only is the home demand entirely supplied, but a large shipping trade has been built up to distant points. Although there are a large number of small yards scattered throughout the state to supply the local demands, the value of the St. Louis output amounts to 64 per cent of the entire state product, and that of St. Louis, Kansas City and St. Joseph 79 per cent of the total product.

Sewer-Pipe. This industry ranks second in importance, for there are five plants with a total capital of $1,025,000, and an annual value of the output of about $1,100,000. Most of the sewer-pipe is made in St. Louis, where there are three large double plants. There are two single plants in the western part of the state. The greater portion of the product is shipped, throughout the Mississippi valley and the west. The base of supply of the St. Louis output is the St. Louis fireclay, in admixture with a lesser amount of shale or brick clay. The western plants depend mainly on shales as a basis for a mixture with some top clay.

Firebrick. Third in importance is the manufacture of firebrick. There are twelve plants, with a combined capital of $1,150,000, and an annual output that is valued at about $950,000. This also includes some fire-proofing or flooring which is made by some of the St. Louis factories, but not separated in their returns from the strictly refractory ware, as both are made from the same clay. The factories are all in the eastern portion of the state, and mostly in St. Louis, which with its good shipping facilities, sends nearly all of its output outside the state, throughout the Mississippi valley, as far east as the Atlantic seaboard, and as far west as the Pacific. The industry is founded on the Cheltenham fireclay seam which furnishes a very superior grade of plastic clay that is used as the basis of the mixture at all the plants.

Burnt Ballast requires much less capital, in proportion to its output, than other lines of ware. In the hand plants there is scarcely any investment, and but little more capital is necessary than to meet

the running expenses. Even the machine plants require only a moderate investment, to secure a large output. Kilns are not required, and these form the heaviest item of expense in equipping any other kind of clay-plant. The capital invested to produce the $1,000,000 worth of burnt ballast a year is estimated very liberally at $500,000, though this is probably considerably in excess. This industry is entirely confined to the northern half of the state, where natural ballast is usually poor and scarce, but where there is a great abundance of gumbo clays that are admirably adapted for this purpose.

Paving-Brick. This industry is of recent origin not only in this state but elsewhere in the country. Yet there are thirteen plants in the central and western parts of the state devoted to this line, that have an estimated combined capital of $235,000, and which produce about $350,000 worth of paving brick a year. They all use shale which is abundant in the northern half and western portions of the state. This industry is likely to show a rapid growth.

Stoneware. There are represented 42 plants, all of which, with one exception, are small hand potteries. The capital invested is estimated at $210,000, and the annual value of the product is about $170,000. There is an abundance of raw material for this industry throughout the greater portion of the state, but the large well-equipped steam potteries of Illinois, Ohio and Indiana have nearly captured the large markets in the state and there seems to be no disposition to recover them on the part of the Missouri potters.

Terra Cotta. Next in value is the terra cotta industry with an estimated capital of $135,000, and an annual output that is estimated at $62,000. There are three works, only one of which is now in operation, although this one is meeting with marked success. The other two plants are small, and thus far have not done much. Two are in St. Louis, and the other is in Kansas City.

Draintile. There are 37 plants altogether. They are all small local concerns that represent a total capital of about $58,000, and the annual value of the output is about $50,000. They are scattered throughout the northern half of the state, where they are urgently needed in many of the flat prairie districts to furnish cheap drainage material.

Roofing Tile. This is the youngest clay industry in the state. A plant has just been built in St. Louis for this speciality. A capital of $50,000 is invested, and the estimated value of the annual output is placed at $40,000.

Flower-pots. Several small plants manufacture flower-pots. They have an invested capital of about $30,000, and an estimated annual output of $30,000.

Summary. The summary of the clay industries here given is a very close approximation except in the case of the small brickyards and potteries. In the latter cases it was very difficult to get reliable or official returns so that many estimates had to be made.

Summary of Missouri Clay Industries.

No. of plants	Kind.	Capital.	Value of product.
358	Building brick	$3,434,000	$3,496,966
5	Sewer-pipe	1,025,000	1,110,000
12	Fire brick	1,150,000	945,000
10	Burnt ballast	512,500	1,025,000
13	Paving brick	234,800	347,000
42	Stoneware	210,000	168,749
3	Terra cotta	135,000	62,125
37	Draintile	58,000	48,287
1	Roofing tile	50,000	40,000
7	Flower-pots	30,000	30,700
488	Totals	$6,839,300	$7,273,827

CHAPTER II.

THE GEOLOGICAL OCCURRENCE OF CLAYS.

(BY CHARLES R. KEYES.)

No class of mineral deposits that are utilized widely in the arts are so entirely dependent upon the geology of a region as are the clays; and no deposits of commercial importance correspond in their geographical distribution so closely with the range in space of the commonly recognized geological formations; nor with such unerring certainty can the local presence of any other mineral substance be predicted from a glance at a good geological map. It is not only the mere presence of clay deposits that can be thus inferred but with reasonable accuracy the particular kind and variety. On account of this intimate association of the clays with certain of the numerous geological formations a brief sketch is given of the latter as they occur in Missouri. The importance of a connected description of various formations in which the principal clay beds are designated is more fully appreciated by those who are accustomed to look at such phenomena from a strictly geological point of view, but at the same time it is a feature that is not to be overlooked by those with whom it is not customary to investigate in a broad way deposits of economic value. It is those in particular who are to derive the chief, direct and immediate benefits.

In connection with the local details concerning the occurrence of the various kinds of clays much geological information is incorporated but a general and connected consideration of the geological and geographic distribution of the clay deposits is properly a theme requiring brief treatment by itself.

GENERAL CONFIGURATION OF THE SURFACE OF THE STATE.

Topographically the state of Missouri is readly divisible into three very distinct areas. These are the northwestern upland plain, the Ozark dome and the southeastern lowland plain. The boundary between the first two districts is the Missouri river from its mouth to Boonville in the central part of the state and from thence southwestward to the south line of Kansas. The line of division between the last two is a line passing due southwest from Cape Girardeau on the Mississippi river, forty miles above the mouth of the Ohio.

In its surface relief the northwestern plain, which is practically occupied entirely by coal measures, is gently undulating, moderately elevated and inclined southeastward. Into this plain the larger watercourses have cut their channels rather rapidly to a moderate depth. On this account the country adjacent to the streams is much more broken than in the interior and the surface often descends abruptly. The general elevation of the southeastern border of the tilted plain is about 800 feet above tide level. Below this horizon the streams have cut troughs 150 feet or more in depth. The highest portion of the plain is in the extreme northwestern corner of the state where the altitude is over 1200 feet above the sea. The difference in the extremes of elevation within the limits of the area is therefore about 600 feet.

The Ozark region is geologically an area of decided uplift, and forms a dome-like elevation which is bowed up from the Missouri river to the Red river of Arkansas and from the Mississippi to Indian territory. Southern Missouri constitutes only a part of the elevated district. While as a whole the general surface slopes gently in all directions from center to margins it is deeply trenched on all sides, and in the eastern part the country is so rugged that the designation St. Francois mountains is very appropriately applied. The elevation of the uplift is from 1200 to 1800 feet above its margins and from 1700 to 2100 above sea level. The uplift is occupied by the oldest rocks exposed in the state. In the St. Francois district are the ancient crystallines, the granites and porphyries of probable Algonkian age. The rest of the region is occupied by a great series of dolomites and sandstones of Cambrian and Ordovician age. Around the base of the dome are narrow belts of Silurian, Devonian and lower Carboniferous strata.

The southeastern lowland forms a part of the great flat plain of the Mississippi embayment. It is made up of unconsolidated clastics chiefly of Tertiary age.

THE GEOLOGICAL FORMATIONS AND THE PRINCIPAL CLAY DEPOSITS CONTAINED IN EACH.

Algonkian. The name Algonkian, as first introduced into the literature of Missouri geology, referred to certain conglomerates which bear the iron ores of Pilot knob and vicinity. They rest directly upon the porphyries and have the Cambrian sandstones and limestones superimposed. Most, if not all of these ore beds are without doubt a part of the Cambrian and do not belong to older formations. There is reason, however, for believing that the massive crystallines of the region

are not really of Archean age as generally considered, but true Algonkian. These rocks in part represent very acidic magmas which are now granite and quartz-porphyry. In chemical, mineralogical and structural characters these rocks are very different from the gneissic and schistose rocks which have been reached in deep drill-holes. Therefore, while they are thought to be later in origin than the gneisses and while there is no proof that they do not actually belong to the Archean their manifestly much later date of protrusion would suggest that they are not contemporaneous with the gneisses but probably should more properly be placed in what has been called the Algonkian. That the porphyries are pre-Cambrian is certain, for the reason that the sedimentaries rest in marked unconformity upon them. That they are younger than the gneisses is equally manifest, because they have undergone not the slightest squeezing and they have therefore had their origin long subsequent to the period at which the schistosity was produced. The porphyries may have been produced during the later Archean, but it seems more probable that they should go in that long intervals between the most ancient formations and the first sedimentaries of the region.

Although these crystalline rocks are largely feldspathic and are of the same constitution as those from which most clays are derived in the process of disintegration and decomposition, the geological conditions are such that no valuable clays are liable to be found in connection with them. The peculiarity of these exposures is that they are old hills formed in pre-Cambrian times and completely covered by sedimentary beds. At the present time they are being exhumed through erosion. As yet they have been subjected to very little of the modern influences of degradation.

CAMBRIAN.

The strata now referred to the Cambrian are found chiefly in the crystalline region of the southeast. They are the rocks which immediately surround the porphyry peaks. Their known maximum thickness is in the neighborhood of 700 feet. The exact upper limit is not yet fixed and consequently the geographical extent except in a general way remains undetermined. On stratigraphical grounds rocks of this age are regarded as including at least three distinct members, the lowermost of the so-called magnesian series of the region. These are the LaMotte sandstone, the Fredericktown dolomite and the LeSueur limestone.

The first of these, the LaMotte sandstone, includes a basal conglomerate which is composed largely of water-worn bowlders and peb-

bles from the underlying crystallines. Little clay is associated with this formation. At the base, however, there are often thin seams of shale, and considerable argillaceous material is often mingled with the matrix in the basal conglomerate beds. West of Fredericktown, for example, one bed of red and green shale which weathers to a plastic clay has a thickness of 13 feet.

The Fredericktown dolomite immediately overlies the LaMotte formation and is a characteristic non-cherty magnesian limestone. There are two rather well marked subdivisions recognizable, the lower one being in the main an ordinary grayish limestone with some sandy material and shaly layers; and the upper a buff dolomite tolerably free from silicious matter. The lower portion is the chief ore-bearing rock and contains a number of beds of blue shale which are fossiliferous. In some parts there is, towards the base, certain peculiar layers which are called the marble beds. These are hard, compact, very fine-grained and susceptible of taking a high polish. They frequently contain fragments of porphyry. The dolomite often has intercalated thin beds of shale. One stratum of blue argillaceous shale at Mine la Motte, north of Fredericktown, is 15 feet thick. Near Bonne Terre a similar shale 30 feet thick is exposed in the bluffs of Big river, and less heavy beds are found at numerous other points. Many are over six feet thick and all break down into a plastic clay that is utilized as yet only sparingly.

The LeSueur limestone is a very cherty dolomite which resists weathering influences much longer than the non-silicious underlying limestone. The layers are not so thick as in the Fredericktown beds and the presence of large quantities of chert give the strata the appearance of being very thinly bedded. No clayey layers of importance are known from this horizon.

ORDOVICIAN.

The rocks of lower Ordovician age occupy a large portion of south Missouri, in fact they are the surface formations of nearly all the Ozark dome. Only along the eastern border of the uplift are the upper Ordovician strata present. They form a narrow zone bordering the Mississippi river. The rocks comprise magnesian limestones for the most part and to this portion the title Ozark series is restricted. The term as originally proposed was intended to cover all the Magnesian limestones of the Ozark region but in this sense it includes rocks of both Cambrian and Ordovician age. Since by far the greater portion of the Magnesian strata belong to the latter, the title can with propriety and advantage be retained for these alone. On most of the Ozark dome the minor subdivisions of the Ordovician have not been made out.

In the eastern part successive narrow belts occur of the Crystal sandstone, First Magnesian limestone, Trenton limestone, Hudson shales and above these the later Silurian and Devonian formations. The various deposits of workable clays occur not as extensive layers interstratified but as numerous local and limited pockets that have accumulated in late erosion basins in the general surface of the rocks. Such are the deposits of china and ball clays, the flint fireclays, and certain potters' clays to which frequent mention is made elsewhere. Besides these are numberless beds of residual clays which are the yellow and brown, highly plastic clays that are everywhere present, though usually mingled with chert and sand.

Crystal Sandstone. In its typical development the sandstone of Crystal City attains a thickness of 50 feet. Heretofore it has been commonly called the Saccharoidal or First sandstone, but it is not to be confounded with the similarly designated sandstones of other parts of the state which belong to many different horizons. On the Mississippi river north of the mouth of the Missouri a sandstone having nearly the same stratigraphic position has been correlated with the St. Peter sandstone of Wisconsin, but it is not believed that this parallelism is at all probable. The Crystal sandstone is usually white in color though often shaded red and brown. It is very homogeneous in texture, massively bedded, but is usually rather friable. So incoherent is it that it is little more than an ordinary sand bed. Occasionly hard layers occur which form good building stone. These layers are so hard and vitreous as to resemble quartzite. Their origin is probably due to the enlargement of the component quartz grains through the secondary deposition of silicious matter. Fossiliferous remains are of rare occurrence. No shale or clay seams are known in this formation.

First Magnesian Limestone. The uppermost of the magnesian limestones is usually a heavily bedded dolomitic rock, not always very compact, but withstanding well the effects of weathering. Its greatest thickness as determined by Shumard is over 150 feet. In the eastern part of the state it immediately underlies the Trenton limestone, but in all other parts the latter is not represented, having been removed through erosion. As the overlying Trenton is such an easily and accurately determined horizon throughout the whole of the Mississippi valley the exact correlation of the First limestone formation should not be difficult. It appears to be the representative of the Oneota limestone of Wisconsin and northern Iowa, the St. Peter sandstone being absent in Missouri. In color it varies from light yellowish gray to a rather dark buff or drab. The light soft earthy layers are widely known as "cotton rock." The clayey seams are very unimportant and

seldom are over two or three feet in thickness. They are, moreover, usually too calcareous to be utilized to advantage.

Trenton Limestone. No formation of the Paleozoic in the whole Interior basin possesses so marked and so persistent features, by which it may be readily recognized whenever exposed, as the Trenton. As now understood the Trenton limestone embraces not only the Trenton proper as understood in the earlier geological reports of the state, but also the so-called "Black-river" and "Birdseye" limestones. The latter two may be regarded as the lower or less fossiliferous portion of the formation, as it is nowhere separated either faunally or lithologically from the upper part containing the typical Trenton forms of organic remains. The lower Trenton is a compact, heavily bedded limerock often approaching in texture certain lithographic stones. It contains comparatively few fossils. The upper Trenton is exposed chiefly along the Mississippi river from Marion county to Cape Girardeau. In its northern part it is composed of bluish or grayish limestone intermingled with brown earthy strata which sometimes make up the greater portion of the formation. Occasionally shale partings are present. Fossils are abundant in places, but are usually in the form of casts. South of the Missouri river the limestone becomes a massive or very heavily bedded compact bluish-drab rock with abundant fossils. The interbedded argillaceous material in the Trenton is insignificant. The geographical range of the formation, however, is important as marking the limits of occurrence of very pure clays of residual character that are found in shallow excavations in the surface of the formation everywhere that it occurs.

Hudson Shale. Although having a maximum thickness of more than 75 feet the Hudson shale is unimportant stratigraphically. It lies between two great limestones, so that its surface extension is everywhere reduced to a mere band and the outcropings are usually only in vertical bluffs. The shales are blue or greenish in color, calcareous and rapidly break down upon exposure to the weather to a soft plastic clay. Numerous thin bands of limestone are intercalated and towards the base they form layers of considerable thickness. The geographical distribution is essentially the same as for the Trenton limestone. Fossils are abundant throughout the range of the formation and are in an excellent state of preservation. They are identical, specifically, with those so characteristic of the same formation at Cincinnati, Richmond (Indiana) and northeastern Iowa. The geographical area of these shales is comparatively limited being confined chiefly to a narrow zone in Pike county and along the Mississippi river in the southeastern part of the state.

Girardeau Limestone is a formation that is only found on the eastern border of the Ozark uplift. It was first recognized by Shumard who placed it in the upper instead of the lower Silurian. Lithologically it is a bluish, compact limestone, rather thinly bedded and everywhere fractured by numerous joints. Fossils of peculiar types occur. The thickness of the formation is about 60 feet. No shale beds of workable thickness appear to occur in the formation, which itself is only exposed in a very narrow belt in Cape Girardeau county.

SILURIAN.

As in the case of the greater part of the Ordovician the Silurian formations are confined to the extreme eastern border of the state and chiefly to the eastern extremity of the Ozark uplift. On the whole they are unimportant stratigraphically. Several thin beds of clay from four to six feet in thickness are believed to belong to this formation but they are of little value commercially as those localities in which they occur have other much more extensive deposits of clay in other formations.

Perry Limestone. The strata which in the Mississippi valley have been commonly called the Niagara are not very clearly defined in any part of the state. They are exposed only in the extreme eastern portion of the state chiefly along the Mississippi river and usually form a part of vertical sections, so that the surface extent is practically confined to a very narrow belt. Certain of these beds are doubtless equivalent to the so-called Niagara of other parts of the Mississippi basin, but the faunas contained are not closely enough related to admit of covering both sets of strata by a common name. With these peculiarities in character and with the desirability of having a special geographic title with which to designate these rocks it is intended to use the name Perry limestone, from the county in Missouri in which the beds were first described. This addition to the nomenclature seems preferable to the reviving of the old name of Clear Creek proposed by Worthen though it covers nearly the same space. These limestones attain a maximum thickness of 300 feet. They are rather light grayish or bluish in color and contain considerable clay in certain layers. Fossils abound in some beds.

DEVONIAN.

Grand Tower Limestone. Of all the Paleozoic rocks which are exposed within the limits of the state the Devonian is the most poorly developed. The beds occur only in the eastern part of the state and along a portion of the northern part of the Ozark dome. The two

members as represented in Missouri appear to replace each other to some extent. Whenever the lower part is well represented, the upper portion is almost or wholly wanting; so also in those localities in which the upper portion is well developed the lower beds are entirely absent. The Grand Tower limestone is only known along the Mississippi river south of the mouth of the Missouri. In the main the formation consists of shaly, somewhat magnesian cherty limestones which are gray in color, and often very fossiliferous. The formation corresponds to what has properly been referred to the Onondaga and Oriskany of southeast Missouri and southwestern Illinois. The fauna contained appears to differ very much from the typical faunas of the Western Hamilton in other parts of the Mississippi basin. Only thin argillaceous beds of limited geographical extent are known, and nowhere are they of very great economic value.

Callaway Limestone. The upper member of the Devonian contains the so-called Hamilton fauna of the west and very properly may be regarded as representing that formation of adjoining states. The name as applied refers to the Devonian limestone above the Grand Tower beds. Its distribution is almost entirely along the Missouri river where it follows the northern margin of the Ozark dome and finds its best development in Callaway county. Although restricted in distribution this formation is the most important of the Devonian strata occurring within the limits of the state. Its upper part is somewhat thinly bedded and passes into calcareous shale which may belong in part to the so-called black shale. In its typical development it has a thickness of 60 to 70 feet. The lower portion is a compact, blue or buff to brown limestone which passes upward into shale and becomes highly fossiliferous. The shaly portion is 30 feet thick in Callaway county.

"Black" Shale. In northeastern Missouri there occurs immediately below the "Kinderhook" some dark-colored shales which have been regarded as corresponding to the "black shale" of Illinois and the region farther eastward. In the eastern part of Pike county along the Mississippi river the thickness is not more than 10 feet, but westward a vertical measurement of 40 to 50 feet is attained. It is fossiliferous in places the most characteristic forms being fish teeth and bones, with a few small brachiopods.

CARBONIFEROUS.

In Missouri the Carboniferous is a three-fold formation, the median member of which contains the great deposits of mineral fuel. The inferior subdivision is the floor over which the coal-bearing de-

posits were laid down and it is an important and characteristic horizon, below which no prospecting for fuel should be carried on. The median member is fully considered elsewhere. The superior member constitutes the barren coal measures though there are a few thin seams of coal present that can be worked.

Mississippian Series. The Carboniferous limestones, or lower Carboniferous, is the present eastern limiting formation of the coal measures over most of the Missouri region. It comprises four principal subdivisions, each of which is divisable into a number of minor members. The leading subdivisions are the Kinderhook beds, the Augusta limestones, the St. Louis limestones and the Kaskaskia formation. The characteristic feature of the series as compared with the coal measures is the great predominence of limestones, almost to the total exclusion of any shale beds, while in the higher series the reverse is true.

The Kinderhook beds which form the basal portion of the Mississippian or lower Carboniferous series consist of two bluff limestones, between which are green argillaceous beds called the Hannibal shales. The Hannibal, or vermicular shales of Swallow, have a maximum thickness of more than 70 feet at the typical locality in Marion county. They are fine, bluish or greenish, often with considerable amounts of calcareous and magnesian carbonates, forming in places impure earthy bands of magnesian limestone. The upper portion usually contains much fine arenaceous material, passing locally into sandy shales, shaly sandstones and to the northward, especially, into substantial sandrocks suitable for ordinary masonry. The indurated sandstones are largely absent in the southwestern part of the state. Downward the shaly sand beds lose their arenaceous character and pass rapidly into the greenish clay shales, which appear remarkably uniform over broad areas. At Burlington, Iowa, excavations show a thickness of more than 70 feet, while borings indicate double this vertical measurement.

In southeastern Missouri the exact equivalents of this formation are not definitely understood. In Ste. Genevieve county certain variegated clay-shales below the Burlington limestone have been referred to the vermicular of Swallow. Worthen has also regarded as Kinderhook a series of argillaceous and silicious variegated shales found immediately above the "black shale" of the Devonian, in the adjacent parts of Illinois.

Westward from the typical locality, the Hannibal shales become more calcareous and much thinner, in some places being apparently unrepresented, while the overlying limestone, Chouteau, rests directly upon the Ordovician magnesian limestones. This thinning of the formation in question seems to be due in a large part to a low anticline

trending northwest and southeast through Pettis, Morgan and Camden counties. Farther southward it is again typically developed. On Pierson creek, seven miles southeast of Springfield, in Greene county, more than 40 feet of this formation are exposed in mine shafts. In Ozark, Douglas and Wright counties Shumard has called attention to isolated patches of these shales with abundant and characteristic fossils. They are well developed in Polk county, where they cap the highest hills of the great magnesian limestone series, suggesting that the entire formation in this part of the state has been mostly removed through protracted erosion, and perhaps as far northward as the Missouri river.

This shale is an important one for the manufacture in paving brick and terra cotta, and entensive plants are using the material from this bed. In its northward extension along the Mississippi river it is used at Keokuk and Burlington. At the former place a large shaft has been sunk to a depth of 300 feet in order to reach the shales of this formation for making paving-brick, while at the latter place high grade pavers are also made on a large scale from it. Along the Mississippi river in Pike and Marion counties occurs a single and almost continuous exposure of these shales that is 60 feet high and more than 30 miles in length.

The second member of the Mississippian series is the Augusta limestone which has an extensive geographical range. Only in the extreme northeastern corner of the state it is known to have commercially valuable clay deposits. Its upper portion, the Warsaw shale, is utilized just outside of the state limits for the manufacture of paving and pressed building brick. The bed is 40 feet thick.

The St. Louis limestone contains in the upper portion clay shales often in beds 15 to 20 feet thick. They are highly calcareous as a rule and are not yet utilized in the clay industry.

The fourth member of the series is the Kaskaskia formation the upper 60 feet of which is clay-shale. Its distribution in Missouri, however, is very limited being confined to a narrow belt along the Mississippi river in Ste. Genevieve county and a few isolated areas in the southwestern part of the state.

Des Moines Series. This term has been applied to the principal coal-bearing formations, and includes all those beds which have commonly been called the lower coal measures. It is pre-eminently a shale formation, for, with the exception of a few very thin limestone layers and a few sandstones it is entirely composed of clay-shales. In geographical distribution it forms a broad belt from 40 to 70 miles wide extending from the northeastern to the southwestern corner of the

state. Beyond this main belt there are numerous outliers of greater or less extent. The value of these clays or shales is rendered much greater from the fact that abundant supplies of fuel are present for burning them.

The prevailing beds associated with the coal are the shales. On exposure to meteoric agencies they quickly disintegrate, forming soft clays which are readily removed by running waters. It is owing to the great preponderance of these beds over all other materials comprising the coal measures that the general surface configuration of the region is so free from marked differences in topographic expression and that the country occupied by the formation nearly everywhere presents softened outlines of relief. Except in the immediate vicinity of larger streams where the currents constantly impinge against the banks, good outcrops are rarely met with.

Four principal varieties are usually recognizable: (1) argillaceous, (2) arenaceous, (3) calcareous, and (4) bituminous. These merge into one another, but in places there may be sharp dividing lines between them. By the gradual addition of fine sandy material they pass imperceptibly into sandy shales, these again into shaly sandstones and finally into hard, compact sandrock. Again, through the increase of lime constituents the deposits grade into calcareous shales, then into earthy limestones and finally to ordinary limerock. Or, in another direction carbonaceous matter rapidly becomes prominent, the shales acquire a dark color, assume a highly bituminous character and finally pass into coaly layers. These gradual transitions take place laterally in the same horizon or vertically from one layer to another.

The clayey varieties constitute much the larger proportion of the shales. They commonly form the lighter colored kinds, drab, or bluish tints predominating, but there are all colors from white or ashen, through shades of red, orange yellow, purple and blue, to black. Variegated shales, in which the various colors appear indiscriminately mingled, are of frequent occurrence. As a rule the strictly argillaceous shales are compact, more or less massive with the lines of stratification poorly defined. When first encountered in artificial excavations, as in railway cuttings or coal shafts, these shales are very hard and tough. During the process of removal they yield but little to the pick and require as much blasting as for ordinary limestone or sandrock. Upon exposure to the weather these shales readily go through a process of "slacking," as it is called by miners, and become compact but highly plastic clays.

Among the most important, economically, of the light-colored shales are the so-called fireclays, which form the underclays of the

coal seams. No matter how thin a vein of coal may be the fireclay is almost invariably found below it. This substratum has a thickness of from one foot to half a dozen or more feet, but ordinarily has a measurement of three or four feet. It is a fine, soft, homogeneous clay, white or ashen in color, highly plastic, and often resists the action of heat in a remarkable manner, hence its name fireclay. The relations of the coal and its underclay indicate clearly that the white layers are to be regarded as the soil which supported the luxuriant plant growth of the ancient marshes, just as at the present time there is found at the bottom of many modern peat bogs a fine clay of similar character. The peculiar properties of the underclays are probably due in large part to the action of the water-loving plants which flourished on this rich submerged soil; for it is a well established fact that aquatic vegetation removes from the soil all or nearly all of the alkalies, iron, sulphur and a considerable percentage of the silica, leaving finally a light-colored clay rich in alumina. The abstraction of the alkalies from the clay takes out those constituents which act as fluxes when the substance is highly heated. In ordinary clays these materials allow melting when brought in contact with fire, forming a glass-like mass, which is in reality a complex system of small glassy threads binding together the impurities. In the under or fireclays the absence of fluxing components prevents the mass from fusing. But not all of these clays are highly refractory and a large number and perhaps the majority are too fusible for refractory ware and are hence adapted for pottery and other ware that are not to be subjected to high temperatures.

The highly bituminous shales, the sandy shales and the highly calcareous shales are not so important as those mentioned for the reason that they cannot be used except through special treatment to remove the objectionable impurities, and associated with them there are always extensive beds of the purely argillaceous varieties.

Missourian Series. This formation comprises essentially the "upper," or barren, coal measures of northwestern Missouri. As in the lower division of the coal measures or Des Moines series the argillaceous materials of the upper part predominate over the other components. But instead of being dark-colored as a rule the clays of the upper division are light colored, calcareous rather than bituminous. The transitions from one lithologically distinct bed to another are much more gradual and layers are far more presistent than in the lower coal measures. A pure clay stratum acquires more and more calcareous material until through various shaly stages it eventually becomes a well-marked limestone. The clays carrying a high percentage of lime

are popularly termed "marlites." Although there are some bituminous shales, they are for the most part, quite limited.

There are besides the ordinary shales extensive underclay beds beneath the thin coal seams and these are utilized for both pottery and refractory ware.

CRETACEOUS.

Within the limits of the state the only Cretaceous deposits now existing are in the southeastern part. In the bluffs of the Mississippi river in Scott county there are certain arenaceous beds which lie beneath the so-called Eocene and which are with some doubt referable to the Cretaceous. They rest unconformably upon the magnesian series and have the overlying beds superimposed unconformably upon them. In the northwestern part of the state the Cretaceous beds are known to exist within a few miles of the state boundary. Doubtless they extended for a considerable distance over the coal measures of the region, possibly covering at one time the greater part of the state. With the beds of this age so near it is not improbable that outliers of the Cretaceous will eventually be found to exist in this part of the state. The clays of this geological age are unimportant so far as now known.

EOCENE.

The Tertiary formation occupies the greater part of the lowland plain in the southeast. Its most prominent relief feature is Crowley ridge. The deposits consist largely of unconsolidated sands and clays. The beds of the latter are extensive and include varieties that are suitable for refractory goods and stoneware. The future supplies from this district are destined to be large.

PLEISTOCENE.

The later deposits comprise the loose materials which form a mantle over the northern half of the state obscuring the older indurated rocks. There are two well defined phases called the glacial drift and the loess. The most typical occurrences of the latter are along the great streams, for a distance of five to ten miles on either side. They comprise fine pebbleless clays that are extensively used for brick. The drift includes a heteogeneous assemblage of materials among which are common brick clays and occassionally potters' clays.

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CHAPTER III.

CHEMICAL PROPERTIES OF CLAYS.

Pure clay is a massive, amorphous variety of the mineral kaolinite, or a mixture of two closely related minerals, kaolinite and pholerite. Kaolinite is an hydrous silicate of alumina, with the formula $Al_2O_3, 2SiO_2+H_2O$, and has the following composition:

	Per cent.
Silica (SiO_2)	46.3
Alumina (Al_2O_4)	39.8
Water (H_2O)	13.9
Total	100.0

Kaolinite crystallizes in the monoclinic system, in transparent, thin plates, with perfect cleavage; hardness is 1 to 2.5; specific gravity 2.4 to 2.6. It is usually plastic and is infusible.

The massive or amorphous variety of kaolinite (called pholerite) constitutes the body or essential constituent in all clays and shales. No clays are found that consist of only pure kaolinite (or pholerite), as variable amounts of certain other minerals are always present, as impurities or foreign matter, and these impurities have a very marked effect on the character and uses of a clay, according to their amount and kind. The impurities are more or less thoroughly intermixed with the kaolinite, and consist of quartz (as sand), feldspar, mica, iron in various forms, calcite, dolomite, gypsum, alum, titanic acid, organic matter and moisture. Some of these impurities are present in every clay. The purest clay found in Missouri showed an aggregate of only 1 per cent impurity, which is exceptionally low, while the most impure sample showed the presence of over 86 per cent of foreign matter, which is remarkably high; yet on account of the non-detrimental character of the excessive amount of foreign matter (85 per cent of quartz or sand) in the latter example, it was as valuable a clay as the former. Another clay with only about 7 per cent of foreign matter was almost valueless, on account of its easy fusibility, which was caused by the presence of certain fluxing impurities. It is therefore very important to distinguish between those impurities which affect the fusibility and color of a clay, which are known as the detrimental, and those impu-

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rities which have no injurious effects on its fusibility and color, and which are known as the non-detrimentals. The amount of detrimental impurities that is permissible depends upon the use of a clay, as a slight amount is even advantageous in a refractory clay, by increasing the strength of the burned ware, while a still larger amount would ruin it, by rendering it fusible. The presence of much iron would ruin a china clay, whereas it must be present in large amounts to make a good terra cotta, brick or paving blocks. The alkalies are advantageous in a potters' clay, and very objectional in a fireclay. Hence, it is necessary to study the effect of the usual impurities and to appreciate their influence and importance.

BASE OF MOST CLAYS A MIXTURE OF KAOLINITE AND PHOLERITE.

That kaolinite is the basis or essential constituent of clays and shales is generally accepted, and a study of the analyses of the 112 clays and shales of Missouri described in this report mainly confirms this idea, as far as the incomplete analyses go; but the analyses of the "flint" or hard fireclays (of the lithomarge type) from the east-central portion of the state and which are exceptionally pure, show that these are admixtures of kaolinite and pholerite.

Pholerite is a well defined mineral that has almost identical physical properties with kaolinite, but chemically it is richer in alumina and water, as the following analysis shows, while it has the formula $2Al_2O_3$, $3SiO_2 + 4H_2O$.

	Per cent.
Silica (SiO_2)	39.8
Alumina (Al_2O_3)	45.0
Water (H_2O)	15.7
Total	100.0

The ratio of the silica to the alumina is as 46.3 : 39.8, or as 1.16 : 1.00 in kaolinite, whereas it is as 39.3 : 45.0, or as 0.81 : 1.00, in pholerite. In the following analyses of "rock" or flint fireclays the silica-alumina ratio varies between the 1.16 of kaolinite and the 0.81 of pholerite thus showing that they are evidently mixtures of these two similar hydrous silicates of alumina.

Table of Flint Clays, showing a mixture of Kaolinite and Pholerite.

Name.	SiO_2	Al_2O_3	H_2O	Impurities.	Total.	$\frac{SiO_2}{Al_2O_3}$ Ratio.
Drake (Gasconade county)	40.50	43.22	14.15	1.93	99.80	0.94
Dry Branch (Franklin county)	42.60	41.88	14.00	1.64	100.12	1.02
Truesdale (Warren county)	43.56	41.48	14.05	1.00	100.09	1.05
High Hill (Montgomery county)	45.12	40.46	13.34	1.06	99.98	1.11
Union (Franklin county)	44.14	39.86	13.84	2.45	100.29	1.11
St. James (Phelps county)	46.33	40.07	13.40	2 00	101 80	1.15
Leasburg (Crawford county)	43.82	38.24	14 94	2.89	99.89	1.15
Kaolinite	46.30	39.80	13.90	....	100 00	1.16
Pholerite	39.30	45.00	15.70	....	100.00	0.81

Of these samples the Drake clay approaches much nearer the pholerite composition than the kaolinite, while the St. James and Leasburg samples are almost identical with the kaolinite ratio; the other four samples fall between these, and they all show that the mixture of the kaolinite and pholerite is variable. These flint fireclays are the only clays that were pure enough to permit an examination of the silica-kaolin ratio from the incomplete analyses that were made. Except in the case of the St. Louis samples only the total silica was determined in the Missouri analyses.

In the St. Louis clays the combined silica was separated from the free or mechanically mixed silica or sand, by digestion in caustic potash and sulphuric acid, in the usual manner; but as the potash attacks even free silica it gives unreliable results. All the St. Louis clays have some feldspar, hence the ratio of combined silica to the alumina was found to vary from 1.15 to 2.06 (in the case of a shale), though the average was about 1.27 in the fireclays. It is therefore impossible to positively say whether the base is only kaolinite, or a mixture of kaolinite and pholerite, though one sample that gives a ratio of 1.15 indicates the presence of some pholerite. The fact that all the other ratios are abnormally high for even kaolinite, in consequence of having either dissolved some of the mechanically mixed silica (sand) with the chemically combined silica, or from the presence of considerable feldspar or other silicates, it is possible that they are all mixtures of pholerite and kaolinite.

Turning to other sources for additional light, as to the probable presence of pholerite in many clays, Cook* in his report on the New

* p. 279.

Jersey fireclays gives 32 analyses, in which the combined silica has been separated from the sand. Of these 32, 21 show the presence of pholerite, by having a less ratio than 1.16 for $\frac{SiO_2}{Al_2O_3}$ as it ranges from 0.94 to 1.15, showing that the majority of them are variable mixtures of kaolinite and pholerite. Of 45 Pennsylvania fireclays given, none have the combined silica separated from the total silica, so that it is impossible to pass on this question with most of them, as the greater portion have so much free sand. A few, however, are sufficiently pure to test the ratio, and ten of these show a ratio below 1.16, or that they are mixtures of kaolinite and pholerite. The Georgia kaolin, from Flowery Bed, gives a ratio of 1.07; the Jacksonville (Alabama) kaolin a ratio of 1.14; and the California potters' clay a ratio of 1.08. The French kaolin gives a ratio of 1.08; the Austrian fireclay a ratio of 1.13; and the Zettlitz (Bohemia) kaolin a ratio of 1.09. Bischof* gives the complete analyses of seven different types of kaolin and fireclays from Germany and Austria and only one of them has a greater ratio (1.20) than 1.16; the other six have less, or range from 1.05 to 1.14, and average 1.10. Of 26 selected analyses given by Dana† to illustrate kaolinite 11 give a ratio of less than 1.16, varying from 1.04 to 1.15. They are all very pure clays and appear at least to consist of mixtures of kaolinite and pholerite.

The large number of American and foreign analyses given farther on are almost valueless for furnishing evidence as to their containing pholerite, as the analyses only give the total silica, and they are too impure from admixed sand and feldspar to determine the ratio of the combined silica to the alumina. The tendency of the other silicates that are liable to be present in clays, as feldspar, mica and wollastonite, would all increase the amount of combined silica, as would also the presence of titanic acid, raising the ratio above 1.16, or that of normal kaolinite. When the ratio therefore falls below 1.16 it may be safely assumed that at least some pholerite is mixed with kaolinite, and the nearer the ratio approaches to 0.81, or the ratio of combined silica to alumina in pholerite, the greater the amount of pholerite present.

The examples mentioned, and in addition the evidence of the purest clays found in Missouri, all show that the mixture of the two similar minerals kaolinite and pholerite in clays is very frequent, and that they occur in variable proportions; and while pholerite seems to predominate in the indurated, lithomarge or "flint" clay variety, kaolonite predominates in the majority of plastic clays.

* Die Feuerfesten Thone, p. 59. † System Mineralogy, p. 474.

INFLUENCE OF IMPURITIES.

The impurities that occur in clays consist of a variety of minerals which vary greatly in amount and kind. A few minerals as sand, feldspar, water and iron are always present to at least a slight extent, and often in large quantities; while there is a much larger number of other minerals that may be present though in variable amounts. Some of these minerals are simple in their composition, as quartz, pyrite and oxide of iron; while many are complex silicates, as the feldspars, chlorite and mica. As the most important property of a clay is its behavior to heat, whether burned into refractory ware, pottery or brick, these impurities are divided, according as they influence the fusibility of a clay into

(a) Non-detrimental impurities; and

(b) Detrimental or fluxing impurities.

The non-detrimental minerals are those which have no effect upon the fusibility of a clay, though they may have a strong influence in affecting plasticity, shrinkage, strength and color. Hence it is very essential to study their influence. They consist of quartz (or sand), titanic acid, water, organic matter and sometimes coal or lignite.

The detrimental fluxing minerals, or the "fluxers," are those which by their own fusibility, or by forming fusible compounds with the clay render it more or less fusible. Some of them also have more or less influence on the color, shrinkage and plasticity. They therefore require very careful consideration.

NON-DETRIMENTAL IMPURITIES.

Silica. The silica that is found in all clays occurs in three conditions:

(1) That which is chemically combined with alumina in the kaolinite.

(2) That which is chemically combined in feldspar, mica, and other silicates; and

(3) That which occurs as free silica, quartz or sand.

The silica in the first condition is that which with the alumina and water makes up the kaolinite or the base of clay. This is the only silica that is present in a perfectly pure clay, and it is 46.3 per cent of the alumina present if the clay has kaolinite for a base; or 39.3 per cent if pholerite is the base. It should never exceed these figures in the analysis of a clay. If more than these amounts are found it shows the presence of foreign minerals, either as silicates, or as free quartz sand.

2. The silica in the second condition, combined in the form feldspar, mica or hornblende, is present as an accesory or foreign constituent. The amount that occurs in this condition is very variable, ranging from 0.5 to 6.0 per cent in the high grade clays, from 5 to 12 per cent in the fair grade clays, and from 10 to 25 per cent in the inferior clays. It is very difficult to accurately determine the amount of silica present in these foreign silicates, on account of the great variation in their solubility, so that in the analyses where the attempt is made to separate the combined silica, which is usually supposed to include that in all the silicates (kaolinite as well as feldspar), from the free silica or sand, part of the silica of these foreign silicates appears with the combined silica, if in the form of mica or wollastonite, or decomposing feldspar, and part with the free silica, if present as fresh insoluble feldspars, orthoclase and albite. The silica present in this second condition is not objectionable in itself, but the bases with which it is associated have a very decided influence on the fusibility and color of a clay. As the latter are determined by themselves it is of no importance for practical purposes to attempt to separate it from the silica in the kaolinite, and the commercial practice of entirely ignoring the above three conditions of occurrence of the silica is quite justifiable for economic reasons.

3. The silica present as quartz or sand in the free condition is an extremely variable factor in clays. Often it can be seen as more or less rounded grains freely disseminated through the clays; more frequently it is so fine that it can only be detected by biting it with the teeth when the "grit" or grains are easily felt; while in kaolins it is often so fine that it needs the aid of a strong lens or microscope to discover its presence. From the mode of formation of clay, whether *in situ*, from decomposing feldspathic rocks, as in kaolin, or whether deposited as a sediment, as in the drift, or the shales of the coal measures, more or less sand in a coarse or fine condition is sure to be present. Cook* found as little as 0.2 per cent in a New Jersey sample, and stated that the average in the best Woodbridge fireclays amounted only to 5 per cent. Some of the Missouri clays have as little as 0.5 per cent, as in the case of "flint" clays from the east-central portion of the state. The excellent fireclays from the St. Louis district have from 20 to 43 per cent of sand, while the fireclays and potters' clays from other parts of the state range from 1 to 55 per cent; the loess or brick clays have from 20 to 50 per cent, the shales from 15 to 60 per cent, and the kaolins from 20 to the remarkably large amount of 84 per cent (Brooks land, Cape Girardeau county).

*Report on New Jersey Clays, p. 273.

The great majority of clays and shales, immaterial as to their quality or uses, usually are from one-fifth to one-third sand, very few less than 20 per cent, and not many exceeding 35 per cent. This free quartz or sand is usually by far the largest foreign substance present in a clay, generally making up at least one-fourth of the weight. While it is a very important physical factor, its chemical action is not great in affecting either fusibility or color. As silica is perfectly infusible by itself, and as kaolinite is an acid or bisilicate, and notwithstanding the fact that Bischof* states that clays are more fusible as the quantity of silica increases, the pyrometric study of 112 Missouri clays shows that the free quartz or sand has no appreciable influence on the fusibility, or at least none that could be detected in the presence of the very important fusibility factors of density, fineness, kind and amount of fluxing impurities. Two fireclays that were similar in density, fineness and freedom from detrimentals were both unaffected in the highest attainable heat of a wind furnace (over 2,700° F.), though one had less than 1 per cent of sand (Kelley bank, Truesdale) and the other had over 40 per cent (Clapper, Monroe county). But while sand or free silica has no influence on the fire-shrinkage or the reduction in volume that clays experience when burnt, all clays when worked up with water to a plastic paste or mud suffer a reduction in volume on air-drying, from a loss of the mechanically mixed water by which they were rendered plastic. It varies from 2.5 to 11.0 per cent, depending on the fineness of the grain and the amount of water used. The free silica appears to have no influence whatever on this air-shrinkage.

On burning, an air-dried clay is found to suffer a second reduction in volume that is due to the driving off of its chemically combined water, which is found to vary from 1 to 15 per cent, and is known as the fire-shrinkage. This fire-shrinkage, which usually amounts to about 5 per cent in common clays and double this amount in very pure clays and kaolins, is found to be affected primarily by the fineness of the grain, the finer, the greater the shrinkage; by the amount of chemically combined water, the more to be expelled, the greater the reduction in volume; by the amount of sand present, as the more contained, the less the shrinkage; and by lime (and magnesia) if present as carbonate, as the more lime, the less the shrinkage. If the latter is present in large amounts (11 per cent as in the Aldrich shale) it may not only entirely prevent shrinkage but even cause the clay to expand. At first thought it may seem as though the fire-shrinkage would be solely a question of the amount of water to be expelled and that the sand and lime by acting as mere diluents would necessarily decrease

* Die Feuerfesten Thone, p. 71.

the shrinkage by displacing that much water. While, as an abstract principle this is true to a considerable extent, it is found that some of the very fine-grained kaolins shrink 15 to 100 per cent more than the reduction due to the loss of their water, while some of the coarse-grained fireclays shrink only one-fifth to one-half of the amount that the loss of the water would lead one to expect. This very great variation in the fire-shrinkage (as also in the air-shrinkage) is found to be mainly due to the fineness of the grain, as the shrinkage increases as the clay becomes finer. The amount of lime present in the great majority of clays is usually too small to affect the shrinkage, so that after fineness the presence of sand becomes the next most potent factor. It is found in comparing clays of equal fineness of grain that the shrinkage decreases as the silica increases, and that the rate of decrease seems to be proportional to the rate of increase of the sand. While high total silica (over 60 per cent) thus means a relatively low fire-shrinkage, a very sandy, fine clay may shrink more than a slightly sandy, coarse clay.

Titanic Acid, TiO_2, or the dioxide of titanium, is a white, infusible compound that is found to a slight extent in almost all clays. It rarely amounts to 2 per cent and in this small amount it is an inert, harmless impurity. It is probably this substance which gives the peculiar bluish gray color that so many clays exhibit after prolonged or very intense burning. Seger's experiments show that when the titanic acid exceeds 6 per cent it has a slight fluxing action, which becomes very pronounced when it exceeds 10 per cent; but as such large amounts have not been found in clays, it is classed with the non detrimental impurities, though it is well to bear in mind that it may possibly occur in objectionable quantities.

It was only determined in the St. Louis series of the Missouri samples, which are all from the coal measures, and in these 13 fireclays and shales it was found to vary from a trace to 1.91 per cent, averaging about 1 per cent. The washed clays were found to contain more than the unwashed clays, as the following percentages show:

	Christy.	Coffin.	Jameson.	Sattler
Raw clay	0.96	trace (?)	1.05	1.85
Washed clay	1.07	1.81	1.36	1.91

The results show that the titanic acid occurs in a very fine condition, and hence it is concentrated by the process of washing into the finer or washed portion of the clays. This explains how it is so universally found in clays, and as it always occurs in such a fine degree of comminution, as its origin would seem to imply, it is only deposited with the finest or clay particles after the disintegration of the rocks

from which it is derived. This is further verified by the coarser of the St. Louis clays having less than the finer. The occurrence of small amounts of titanic acid in the St. Louis clays verifies Cook's work on the New Jersey fireclays (Cretaceous). It was found to be nearly always present and to range from 1.06 to 1.93 per cent, averaging about 1.5 per cent. In 11 out of 16 Ohio clays (coal measures) it was found to range from 0.16 to 1.68 per cent, averaging 1 per cent; in 22 Pennsylvania fireclays (coal measures) from 0.78 to 4.62 per cent, with a mean of 1.50 per cent. Six of the latter showed over 2 per cent and 2 over 4 per cent, which is unusually high.

The origin of the titanic acid is undoubtedly from the ilmenite or titaniferous iron ore that is so very abundant, in fact almost universal, in the igneous feldspathic rocks, from which all clays are primarily derived, but as this ilmenite usually occurs in very small amounts the clays seldom contain much titanic acid, and the above exception in six of the Pennsylvania fireclays, which have from 2 to 4.62 per cent, is an exception that rather verifies the rule, as there are occasional local occurrences of granitic rocks that are comparatively high in disseminated or segregated occurrences of titaniferous iron ore.

In the large number of analyses of the United States and foreign clays, the titanic acid is seldom given, being undetermined in commercial analyses as it has no injurious effect. Even in many scientific analyses it is either overlooked or neglected. When not separated out it appears with the silica in the usual method of making a clay analyses, though in some cases it is determined as alumina. The universal occurrence of titantic acid in clays was pointed out by Riley*, who found from 0.42 to 1.05 per cent in English clays.

Water is found in all clays,

(1) As moisture, or mechanically mixed, and

(2) As water of hydration, or chemically combined.

1. All clays or shales when freshly dug are more or less damp from the moisture that they contain, which may amount to from 3 to 10 per cent in the lump condition, or from 15 to 35 per cent if in the form of a paste or mud. On exposure to air this moisture largely evaporates, and when the clay seems perfectly dry to the touch and is what is known as air-dried, it still contains from 1 to 5 per cent, according to the fineness and density of the clay. There is seldom less than 2 to 3 per cent in seemingly perfectly dry clay. It is this moisture or mechanically mixed water which, when amounting to 15 to 35 per cent, gives the clay its plasticity and permits of its being moulded. The loss of this water of plasticity by evaporation causes a shrinkage of the clay

* Quart. Journal Chem. Soc., vol. xv, p. 311, 1862.

which varies from 2 to 5 per cent in coarse clays and from 5 to 10 per cent in fine clays. When the air-dried clay is heated to a temperature of 212°F. (100°C.) the last of the moisture is expelled and the clay then only contains the chemically combined water. The object of "water-smoking" a kiln of "green" ware is to drive off the last of this moisture. If done too rapidly steam is generated faster than it can escape through the very small pores of the clay and hence causes the ware to crack or even burst into pieces. Thin ware, as plates and saucers stands rapid water-smoking, as the moisture readily escapes through such thin material, and ware that has a large amount of "grog" or pre-burned material also stands rapid water-smoking, as the grog renders it very porous. Thick goods, especially without "grog," as paving brick or furnace blocks, need very slow heating to give this moisture time to escape.

2. The chemically combined water of a clay is part of its molecular constitution and amounts to 13.9 per cent in kaolinite to 15.7 per cent in pholerite; but as clays always have some impurities which dilute or lower this water of hydration, the amount of chemically combined water is less than this, but it is always fixed or constant for a given clay and never varies as does the moisture. On account of most clays being mixed with one-fifth to one-third sand, besides more or less feldspar, the amount of chemically combined water usually ranges from 5 to 12 per cent, and averages about 8 or 10 per cent. The higher the chemically combined water in a clay is found to be the purer the clay in nearly all cases; but in the commercial analyses of clays this chemically combined water is usually determined by simple calcination, without paying attention whether only water, or also carbonic and sulphuric acids are given off. Hence, if the clay contains organic matter, carbonates or sulphates, this chemically combined water is reported higher than it really is, and in this case the seemingly high water percentage is no indication of purity, when reported as "loss on ignition." The chemically combined water is not affected by heat until a black red heat is attained, or about 1,000° F., when it is more or less completely driven off, and the clay loses its property of plasticity. If a clay is exposed to a red heat it is found that it can no longer be rendered plastic on mixing with water, however fine it may be ground. But while the loss of this chemically combined water destroys the most valuable feature that the clay possesses it is not the factor that gives clay its plastic value as is often erroneously thought, for many crystallized kaolinites are non-plastic, while some very pure flint clays which have from 13 to 15 per cent of chemically combined water are very but slightly plastic.

Organic matter. Many clays and most shales are colored by organic matter, and occasionally contain also fragments or very thin seams of coal or lignite. Green, yellow, most red and many brown clays are colored by mineral matter, usually iron. The organic coloring matter gives the clays various shades of grays, drabs, browns, reds, blue and black, and is derived from the finely divided organic matter that settled with the clay or shale particles at the time of deposition. Or, it was derived from the aquatic plants that rooted in the mud that has since become consolidated into clay or shale. This organic matter seldom amounts to much in quantity, as it rarely exceeds 5 per cent, and is usually less than one-half of this amount. As it is generally dissiminated in a very finely divided condition it is not injurious to a clay as it burns out or is expelled when the clay is heated to a red heat. If coal or lignite occurs in large fragments or seams it leaves more or less porous spots or even cavities in the burned clay, provided it is not removed by screening, or crushed to fine powder and mixed throughout the clay in the process of manufacturing the clay into ware.

The organic coloring matter in a clay very often masks the presence of iron or other coloring oxides which are brought out after the expulsion of the organic matter in burning; thus a very black Missouri clay (Owensville) burns white on the expulsion of the black organic matter, while others quite as dark (Kansas City shale) burn to a bright red color, due to the iron contained, but the presence of which is obscured by the black organic matter. A red clay occurs at Commerce (Scott county) that burns to a buff color from the presence of a small amount of iron only, and does not give the deep red color that would be caused by a large amount of iron which its unburned color usually indicates. A similar red clay is found at Woodbride, N. J., that is used for making "saggers" which is also colored red by organic matter, as it is nearly free from iron. In the great majority of cases a red color shows the presence of large amounts of iron.

DETRIMENTAL IMPURITIES.

Alkalies. The common alkalies, potash (K_2O) and soda (Na_2O), exist in all clays and shales, varying from 0.12 to 4.69 per cent in 112 Missouri samples. They occur in three conditions:

(1) As simple soluble salts or "free alkali," as sulphates, chlorides and carbonates;

(2) As complex silicates, as in the micas;

(3) As double silicates, as in feldspar.

1. The alkalies are probably always present in very small amounts in all clays and shales in the invisible form of simple soluble salts, as all

surface waters contain such salts to at least a slight extent; so that whether a clay or shale is deposited as a marine sediment (when this would be a maximum), or as a fresh water salt, or *in situ* by the decay and leaching of feldspathic rocks, at least a trifling amount of alkalies would remain in the moist clay or shale. This amount is nearly always very small and can usually be ignored, since even if it should occur in exceptionally large amounts, it could be easily and inexpensively removed by simple leaching. In the desert regions of the Far West (Utah and Nevada) where the rainfall is very small, the soluble salts of the alkaline earths and the alkalies which exist in all soils, are concentrated on or near the surface by capillary action and evaporation, so that such soils become encrusted with a thin white coat of "alkali," as it is popularly termed, which may amount to 2 to 10 per cent. In climates with the usual rainfall this concentration cannot take place, as the rain washes the salts back into the earth.

The soluble salts of the alkalies are the most injurious constituents that a clay contains, so far as its refractoriness is concerned, as they have a very powerful action in rendering a clay fusible. Although they are easily extracted by leaching with hot water they are rarely if ever determined, as they are usually found in such insignificant quantities as to be of no importance. If present as sulphates to an appreciable extent they are liable to form blisters or "blebs" on the surface of the ware when it is burned, from the decomposition into sulphuric acid gas at a high heat.

2. Many clays and shales contain more or less mica, in minute flakes or spangles. The name covers a group of minerals which are silicates of alumina, magnesia, iron and potash (or soda) containing from 4 to 12 per cent of potash and soda (mainly the former). The alkalies in this condition are no more injurious than when combined in the feldspars, and as it is extremely difficult to separate the alkalies in the mica from the alkalies in the feldspar it is never done in commercial analyses. As the amount of mica present is usually small the special determination of the alkalies in the micas is not important.

3. All clays and shales contain feldspar, which ranges in amount from less than 1, in the purest clays, to over 25 per cent, in very impure clays. The feldspars are a group of minerals that consist of either silicate of alumina and potash, as in orthoclase, which contains 19.6 per cent of the latter; or silicate of alumina, lime and soda, as in oligoclase, andesite and labradorite which respectively contain 14.2, 6.0 and 4.5 per cent of soda; or silicate of alumina and soda, as in albite, which contains 11.8 per cent of soda; or silicate of alumina and lime, as in anorthite. Orthoclase and oligoclase are by far the most common of

the feldspars, while anorthite is very rare. The feldspars are the primary minerals from which all the clays and shales were originally derived. The different feldspars not only vary from 4.5 to 16.9 per cent in alkalies (the rare anorthite having none) but they differ considerably in infusibility. The most common one, orthoclase, has the highest fusing point, about 2,250°F. (the melting point of cast iron), or a very bright cherry; while oligoclase, the next most abundant one, fuses at about an orange heat, or the melting point of silver (1,733°F.) Hence if a clay contains much feldspar there is a marked variation in the fusibility which not only varies with the amount of feldspar present, but also as to the kind of feldspar contained. In appealing to chemistry for assistance in deciding the last point an analysis only tells how much alkali is contained in a clay, from which it is possible to infer which feldspar is present and to what extent. No positive information on this point can be derived from chemical analyses, and a microscopic examination is necessary to obtain this information. Even with the aid of a microscope the different feldspars cannot always be determined, as they may be so decomposed or "kaolinized" as to prevent their identification.

From the above composition of the feldspars, it will be seen that potash will be the only alkali found in a clay containing orthoclase feldspar, while soda will be found if the feldspar belongs to the plagioclastic group (albite and oligoclase). As orthoclase and oliogoclase are frequently found together most clays contain both potash and soda. Furthermore, if the alkali found in a clay is derived from feldspar only (as is usually the case) it indicates the more fusible oligoclase or labradorite members if it is soda; or the less fusible orthoclase variety, if potash only. Hence the alkalies should be determined separately and not reported together as is now done in commercial analyses. Soda is usually more detrimental in affecting the fusibility of a clay than potash, as in most cases it is due to the more fusible plagioclastic or soda members of the feldspar group.

The alkalies are the most potent factors of all the impurities that affect the fusibility of clay and this effect is the more marked when the alkalies are present in the form of the fusible kinds of feldspar, and still more pernicious if present in the form of soluble salts, though the latter are rarely present in notable amounts. As commercial analyses usually give only the total alkalies, without separating the potash from the soda, the following deductions, drawn from a study of 112 Missouri clays and shales that were analysed and tested for their fusibility by the Chatelier thermo-electric pyrometer, are only given as being of approximate value and are subject to exceptions, while it must

be remembered that the question of density and fineness are always more important factors than chemical impurities in affecting fusibility.

By a refractory clay is meant one that will successfully withstand a temperature of 2,500°F., which is a white heat. If the total alkalies exceed 2 per cent, other detrimental or fluxing impurities are probably present in such large amounts as to make the clay non-refractory, or yielding at temperatures less than 2,500°F.

Amount of Alkalies Permissible in Refractory Clays.

Specific Gravity.	Total Fluxers present: (Fe_2O_3, CaO, MgO, K_2O, Na_2O.	Maximum Amount of Alkalies permissible
	Per cent.	Per cent.
COARSE CLAYS.		
2.25 to 2.50	4.0	2.0
2.25 to 2.50	5.0	1.5
2.05 to 2.25	3.5	1.5
1.75 to 2.05	3.0	1.5
2 25 to 2 50	6 0	1.0
2.05 to 2.25	4.0	1.0
1.75 to 2 05	3.0	1.0
FINE CLAYS.		
2.25 to 2 50	3 0	2.0
2.25 to 2.50	4.0	1.0
2.05 to 2.25	3 5	1.0
1.80 to 2 05	3.0	1.0
1 60 to 1 80	2.0	1.0

The allowable amounts of the alkalies only apply to the refractory clays, or those capable of withstanding a temperature of at least 2,500°F. For pottery purposes much larger amounts are permissible and in fact are an advantage in rendering the clay more fusible, and therefore permitting it to be vitrified with a smaller consumption of fuel. For paving brick the more alkali the better (at least to the extent found in clays), as the vitrification can be secured more rapidly and cheaply by having such fusible constituents. In clays not intended for refractory purposes the alkalies range from 5 per cent in kaolin, china and stoneware clays to 3 per cent in pipe, terra cotta and earthenware clays, and to 6 per cent in paving-brick clays. The alkalies have no influence on the color of a clay, nor apparently on the shrinkage; but if present in large amounts (over 1.5 per cent) they add to the strength or body of the burned ware if brought to the point of vitrification.

Lithia. The very rare alkali lithia may occur in clays on account of the presence of lithia mica (lepidolite). It would be as fluxing, and therefore as detrimental in refractory clays, as the common alkali, potash; but as lithia is very rare it may be dismissed from practical consideration, for even if present it would be reported as part of the total alkalies and therefore credited with its high fluxing value.

Ammonia is another alkali that is very rare as a mineral except as mere traces. Even if it should occur as a very exceptional phenomenon in large amounts it would not be injurious to a refractory clay as it would be volatilized with the water in heating.

Iron is rarely, if ever, absent in clays and shales. It was found to range from 0.15 to 9.35 per cent (calaculated as sesquioxide) in 112 Missouri clays that were analyzed. It has a very great influence on fusibility and color and is therefore a very important factor in all clays; it is very detrimental in refractory and pottery clays, while its presence in certain amount is highly important to obtain a good color in terra-cotta, building and paving bricks. It is found to occur in two conditions that have a radically different influence on both fusibility and color:

(1) As ferrous or protoxide (FeO), in carbonates and silicates, and

(2) As ferric, or sesquioxide, (Fe_2O_3), as in hematite, limonite, mica and pyrite.

1. Iron in the condition of ferrous or protoxide occurs very frequently in shales, and sometimes in coal measure clays (the so-called "fireclays") in the form of carbonate (known as the mineral siderite or clay iron stone). Frequently the latter is found segregated as separate "kidneys" or concretions of large size and more or less rounded or flattened form, that are known as "nigger-heads." The shales and clays that contain siderite are usually dark in color, from the almost invariable presence of organic matter, though a partial oxidation of the carbonate. They are often more or less deeply stained brown when exposed to weathering action. The carbonate of iron is easily detected by dissolving with warm, dilute hydrochloric acid, when it effervescences freely and gives a yellow-colored solution.

Iron occurs in the ferrous condition in some clays and many shales, as various silicates, notably the chlorite group which is dark green, and in the hornblende-augitic groups which are green to black in color. Such shales and clays usually are green-colored or have green streaks. Hydrochloric acid sometimes decomposes these silicates giving yellow-colored solutions (but without effervescence) but more frequently it does not affect them. The aid of the microscope

is generally necessary to positively prove their presence as these silicates can rarely been seen by the naked eye.

Iron sometimes occurs on clays and shales as the prosulphate from the oxidation of pyrite. It can be detected by the astringent sweetish taste that such clays have, as it is readily soluble in water. On account of its easy solubility it can be readily and inexpensively removed by leaching, if found in large quantities in refractory or pottery clays. If contained in notable amounts it shows itself by exuding as an efflorescence when such clays are dried.

The ferrous compounds of iron are probably quite as detrimental or severe in their fluxing action as the alkalies, and hence are very objectionable in refractory clays, if they exceed 1 or 2 per cent. The most common form in which it exists is as the carbonate, which, like the sulphate, on being raised to a red heat, decomposes into ferrous oxide and carbonic acid (or sulphuric acid) the latter escaping as a gas. If the clay is kept at a red heat after decomposing the carbonate and it is sufficiently coarse and porous that the air can enter, the ferrous oxide oxidizes into the less fusible ferric oxide which needs about 150° to 200° F. more heat to cause fusion. Hence many coarse clays that contain iron in the form of the carbonate can be rendered less fusible by a slow process of firing if an excess of air is used, by thus changing the iron into a less fusible form. While commercial analyses nearly always report the iron as sesquioxide, though often occuring as the more fusible ferrous oxide, the latter is usually changed during the process of burning into the sesquioxide and so does no more harm than it is credited with. If the clay is heated in a reducing atmosphere or is so fine that the air cannot penetrate it to oxidize the ferrous oxide then it combines with the free silica to form the very fusible ferrous silicate.

The ferrous salts of iron, if not oxidized in the process of heating, give dark gray to black colors, when burned, according to the amount present, or dark green to black if melted. If slowly heated or kept for a more or less prolonged time at a red heat with an excess of air they can be more or less thoroughly oxidized into the ferric salts, when all graduations from gray buff to brown, to bright red can be produced, according to the amount of iron present and the thoroughness of the oxidation.

2. Iron in the condition of ferric oxide occurs very often in clays and shales as limonite, or the hydrated sesquioxide, $Fe_2(HO)_6$, and less frequently as hematite, or the anhydrous sesquioxide, Fe_2O_3. The former gives the various shades of yellow and brown that are so frequently seen in clays, either coloring the entire mass, as in brick

clays, or as streaks or stains, as in the fireclays. The latter gives the red color to the red and reddish-brown clays, at least in most cases, though occasionally, as at Commerce, Mo., and Woodbridge, N. J., the clay is colored red by organic matter. Often there is a mixture of the brown and red sesquioxides in the clay and the former is converted into the latter when the clay is heated to redness, so that for practical purposes it is immaterial whether the sesquioxide occurs as limonite or hematite as the effect after burning on the fusibility and color are the same in both cases.

Pyrite occurs very frequently in clays and shales, especially those from the coal measures. It is known as "shiners," "sulphur," "brasses," or "mundic" by the miners, and occurs from large balls or concretions down to minute crystals that can only be seen by the aid of a strong pocket lens. It is of a brass yellow color, has a metallic lustre, is very heavy, and though very hard, is very brittle. It is a bi-sulphide of iron (FeS_2), and when heated one-half of the sulphur is driven off, leaving a ferrous sulphide, which is as destructive a flux as any other ferrous salt. Hence is is decidedly objectionable in refractory clays, as it makes black fused spots whenever it occurs, while it is very undesirable as a coloring agent except for producing the blotched, variegated surface that is just now very popular in fancy building brick. In some clays it occurs only as irregularly diffused coarse nodules, or concretions, from which it is easily removed by careful hand-picking, as in the German pot-clays; in others the pyrite is freely disseminated as crystals, which can only be removed by careful washing; and in some clays, the crystals are so fine that even washing does not remove them. In the latter case it does not seriously affect a fireclay if not in large amounts, though it ruins the color for pottery purposes.

Ferric oxide occurs as a silicate in some micas (which have 1 to 26 per cent), in many feldspars (which have 0 to 4.5 per cent), and in a few less common minerals. In this condition it is no less detrimental than the hematite, in affecting the fusibility, while it is less satisfactory as a coloring agent, as in the case of pyrite it will usually produce a spotted appearance from want of uniform dissemination throughout the clay.

Magnetite, the black magnetic oxide of iron, is often found in clays though it is usually of rare occurrence, except in kaolins that have been formed *in situ*. It gives a black spotted appearance to the clay, as it usually occurs in small black crystals. It is easily removed by working the clay up to a thin slip with water and slowly running the

thin paste over powerful magnets, which retain the magnetite on account of its magnetic properties. This is the only iron mineral that occurs in clay which can be removed by magnets, except nails and fragments of tools, which may accidently get into the clay in the operation of mining or washing.

There are a large number of other iron-bearing minerals and under exceptional conditions some of them are often found in clays and shales; but for all practical purposes the preceding minerals are all that are likely to be found in 99 per cent of the clays. Orton* speaks of the possibility of the existence of an iron clay, or a hydrous silicate of alumina and iron, with which he explains certain otherwise difficult phenomena. While analogy suggests the possibility of such a compound, it has thus far escaped the eye of the mineralogist and all the phenomena that clays present can be satisfactorily explained, when the marked difference between ferrous and ferric salts is considered, when the difference in coloring and fluxing power of free oxides and silicates is considered, and when it is remembered that both oxides as well as simple and complex compounds of iron are often present in the same clay; while the marked influence on the fluxing action of the alkalies and alkaline earths, according to their mode of occurrence, and the strong influence of lime (and probably magnesia) in counteracting the coloring action of iron, introduce sufficient complexity of conditions to produce all the variations clays exhibit in color and fusibility, without appealling to any new mineral.

A pyrometric study of the Missouri clays shows that the limits for the maximum allowable amounts of iron in refractory clays can only be approximately given, in view of the complex forms that iron takes as an impurity, and that usually it is only reported in analyses as total sesquioxide, though often occurring as the more fusible ferrous oxide (the latter being often changed, however, in the process of burning into the less fusible sesquioxide). It was found that if coarse and of high density (or specific gravity exceeding 2.25), a fireclay could have as high as 5 per cent of sesquioxide of iron, if the alkalies were under 10 per cent and the alkaline earths did not exceed the same amount, but if a clay was fine and of low density (or specific gravity below 2.0) the iron should not exceed 2.0 per cent. If the alkalies exceed 1.5 per cent, and the alkaline earths exceed 1.0 per cent, the sesquioxide of iron should not exceed 2.0 per cent even if coarse and of high density.

The coloring action of iron on clays and shales varies very greatly in both the raw and burned material, according primarily to the

*Geol. Sur. Ohio, vol. VII, pt. 1, p. 77, 1893.

amount of iron present, to the state of combination of the iron, and to the presence of other modifying substances. In the raw clay the presence in large amounts of pyrite, siderite, sulphate (melanterite), magnetite and a few silicates give no general body color to the clay, though if abundant they show spots or blotches and such clays usually owe their color to more or less organic matter or to decomposition products (limonite and basic sulphates) resulting from the alteration of these non-coloring iron minerals. Limonite, hematite and some silicates (the chloritic group) have a marked coloring action on the raw clay, even if in small amounts, in giving it various shades of yellow, brown, red and green.

In the burned clay the organic matter, which is the most common coloring or modifying agent in the raw clay, is destroyed, and then very small amounts of iron are rendered visible and in a manner that depends upon their mode of occurrence. If the iron occurs as pyrite, magnetite, mica and certain silicates, it gives a brown or black spotted appearance to the ware. If the iron occurs as carbonate, sulphate, limonite, and some silicates (especially the chlorites) it usually gives a general body color to the burned clay that varies greatly in depth of shade and color, according to (1) the amount of iron present, (2) the degree of heat employed, and (3) the kind of heat used (oxidizing or reducing). As the color of the burned ware is so important in almost all the applications of clay an attempt may be made to show the effect of different amounts of iron when present in the latter condition as body-colors, as the former or spotty coloring agents can generally be removed by washing if their presence is objectionable, whereas the latter body colors cannot.

First, as regards the kind of heat employed, it is found that by firing a kiln with a very smoky flame, which means that it has a reducing action, the iron can be converted more or less completely into the ferrous oxide, according to the care employed in obtaining a strong reducing flame by using a very thick bed of coal and the time in which the ware is exposed to this reducing action. The reducing action causes the clays that are high in iron, that would otherwise burn red, to become darker, even black, if sufficient iron is present. If the amount of iron is very small it will result in a white to gray-colored clay that would otherwise be pink to buff. The variation in color from varying the degree of oxidation of the iron can only take place when the ware is exposed to the action of the flame and does not affect ware burned in seggers, which are thereby protected from this action. In actually burning kilns the color is often modified by the ashes of the fuel which are carried over by the draught and which, according to the

kind and purity of the fuel, more or less affect the ware on which they lodge. So also different kilns and different parts of the same kiln often show great variation of color in burning the same clay at the same heat, from want of uniformity in firing, as some fire-holes will be run with an oxidizing action by keeping the grate bars clean and thinly fired, while others will be fired with a more or less reducing action from clinkered, dirty grates carrying thick beds of coal.

The degree of heat has a marked action on the color of clay when the iron is present as a body colorer. Thus the Christy clay, with 0.82 per cent of FeO and 1.81 per cent of Fe_2O_3, is white, when burned in an oxidizing heat at 1,000° to 1,500° F.; pink, when burned at 1,500° to 2,000°; buff, at 2,000° to 2300°; dark brown, at 2,300° to 2,700°.

Many clays with a moderate amount of iron are white to cream-colored at a moderate heat, but deep buff to brown at a high heat. Clays high in lime are often white at low, but yellow at high heats. Clays high in iron are salmon-colored if exposed to a dull red heat in an oxidizing atmosphere, red at higher heats, dark brown to black when about to melt, and often purple, at least in the interior, when completely melted.

The amount of iron that produces different colors when present as a body colorer, is not only dependent upon the degree of heat employed and the reducing character of the flame as just mentioned, but is found usually to be strongly influenced by the presence of lime, and probably magnesia, though the Missouri samples do not furnish sufficient evidence to verify the action of the latter. They act as bleachers, or tend to neutralize the action of iron as a coloring agent. If the lime exceeds 1.0 per cent it is generally found to appreciably modify the color, and the greater the amount, the more marked is its action. Thus the famous Milwaukee bricks have over 4.0 per cent of iron, which ordinarily would give a deep red color to the brick, but they burn white to buff, as the clay has over 15.0 per cent of lime. The Owensville clay with 3.35 per cent Fe_2O_3, 3 per cent CaO, and 0.2 per cent MgO, burns to a white or light gray. Large amounts of lime do not always have this modifying action, which indicates that it probably must be present as carbonate or sulphate or some easily decomposed combination. The Boonville shale, with 3.90 per cent Fe_2O_3, has 2.37 per cent CaO, and 1.47 per cent MgO, yet burns to a good red color; so likewise does the Bowling Green shale, which has 3.82 per cent Fe_2O_3, 3.20 per cent CaO, and 1.03 per cent MgO.

The china clays should be as free from iron as possible, so as to give a pure white color; yet the Mammoth mine clay with 0.71 per cent of Fe_2O_3, and the Regina clay with 1.08 per cent Fe_2O_3, both

burn to a pure white, but each has over 2.0 per cent of lime and magnesia. When the lime does not exceed one per cent and the clays are hard-burned in an oxidizing atmosphere, they usually give a cream to buff color when the iron (as Fe_2O_3) ranges from 1.0 to 2.0 per cent; a buff to brown color when it ranges from 2.0 to 3.0 per cent; a brown to red color when from 3.0 to 4.0 per cent, and a red color when it exceeds the latter. These limits are only approximate and are subject to change from increase in the lime in certain cases (which tends to bleach), and to the more or less favorable condition of the iron, while the influence of temperature and flame action always have the above modifying action.

It is very seldom that clays are free enough from iron to not give a creamy or yellowish tint if made up alone into chinaware, and such ware is known in the trade as "C. C." or cream-colored ware, on account of not being a pure white color. This is "corrected" or removed in practice by either "whitening" the ware by using feldspar or quartz, both of which tend to remove the cream color, especially if liberally used; or by adding a little oxide of cobalt, which by the blue color it would otherwise give, neutralizes the yellow tint and gives a white-colored ware, or a bluish-white ware if too much cobalt is used, on the same principle that bluing is added in washing linen to neutralize the yellow tint.

Lime. Lime is found to some extent in all clays and shales, varying from a trace to 11.08 per cent in 112 Missouri samples. It occurs as:

(1) Silicate, in feldspar, chlorite and mica;

(2) Carbonate, in calcite (limestone) and dolomite; and

(3) Sulphate, in gypsum.

1. The usual silicate in which lime occurs in clays is the feldspar group, all of which contain lime except the potash (or soda) feldspar. As all clays contain some feldspar, a small amount of lime is very likely to be present in this form, though the commonest feldspar, orthoclase, contains none. There are other silicates that occasionally occur to some extent in clays, that contain more or less lime, as the micas, chlorite group, and hornblende-augitic series. These silicates have different degrees of fusibility, but the usual analysis gives little or no clue as to which one may be the cause of the presence of lime, and to obtain this information it requires the aid of the microscope. They are all objectionable in rendering a clay fusible, but they probably have no influence on color, and being already combined with silica, they never produce quicklime with its danger of slacking and swelling if underburned.

2. Lime in the form of carbonate occurs in clays as the mineral calcite and dolomite, which when massive are known as limestone or chalk. Though it can seldom be seen by the eye it can easily be detected by effervescing freely with cold, dilute hydrochloric acid, if present as calcite, or on warming if as dolomite; the solution being colorless, and not yellow as the case if carbonate of iron is present, which also effervesces with the acid. It occasionally occurs as white concretions or pebbles especially in brick clays of the glacial period. Lime in this form is very objectionable in rendering a clay fusible, for while infusible by itself it combines with the free silica and iron to form fusible silicates. It is also very objectionable if a clay is underburned, especially if occuring as pebbles or concretions, as it then forms quick-lime which causes the brick or ware to swell or burst when water penetrates it, from the formation of calcic hydrate. If more thoroughly heated (to a bright cherry heat or hotter) the quick-lime combines with the silica to form silicates which are not affected by water, so that only in underburned ware is the formation of quick-lime liable to cause trouble (as in salmon or soft brick). Dolomite, or the double carbonate of lime and magnesia, is probably about as objectionable as calcite, but it is very much less frequently found in clays and shales. Malms, or the best brick on the London (England) market, were made from a marl or calcareous clay; they are now made, on account of the exhaustion of the marl deposits, from a mixture of clay with 25 per cent of chalk, which burns to a cream or yellow colored brick.

3. Lime in the form of sulphate occurs in clays and shales as gypsum, which is the hydrous sulphate of calcium or lime. It results from leachings from oxidized pyrite (which is a dilute sulphuric acid) acting on calcite or limestone that may be either in the clay itself or in coal or other formations above or below from which it has penetrated the clay. It is often found in the so-called "fireclays" that occur beneath coal seams, as large, prismatic, soft, white crystals, or as thin white scales or seams. It fuses at a cherry red heat, and if free silica is present it combines to form a silicate, with the evolution of sulphuric acid gas, which latter is liable to cause the ware to blister if the clay has already been softened. Gypsum is very slightly soluble in water (1 part in 500) but to too slight an extent to permit of its being profitably leached out when clays are very impure from it. After gypsum has been calcined at a low temperature (under 400° F.) it is known as plaster of Paris and has the property of setting with water, but this property is destroyed at 500° F. As all kinds of clay ware are burned at a much higher heat, this property has no interest to the clay

worker. It is to some extent the cause of "saltpetering" or the formation of a white crust on walls built of underburned brick.

Lime is almost as detrimental as the alkalies in refractory clays, if present as a silicate, when it is probably already combined with the alkalies as feldspar; as carbonate and sulphate it does not appear to be so vigorous a fluxing agent. As these distinctions are not made in commercial analyses only a very broad approximate rule can be given as to the amount permissible in refractory clays. If the alkalies and oxide of iron are each less than 1.0 per cent there can be as much as 2.0 per cent of lime or magnesia in coarse dense clays, without causing fusion below 2,500° F., or the highest heat usually attained in furnace practice. If the alkalies exceed the limit mentioned, or the iron exceeds 20 per cent, the lime (or magnesia) should usually be less than 1.0 per cent.

Lime has very often a decided bleaching or whitening effect on clays containing iron, as it tends to more or less neutralize the coloring action of the iron. As it does not always have this action the phenomenon appears to depend upon the condition of the lime and probably also of the iron. If the lime is present as carbonate or sulphate the bleaching effect seems to be most decided, and then begins to be noticeable in its action if it exceeds 1.0 per cent. Hence, in clays intended for pottery purposes or light terra cottas, lime is an advantage, if not present in amounts over 3.5 to 4.0 per cent, in giving white or light color to clays that would otherwise burn buff to brown, or red, according to the amount of iron contained. The silicate probably has little, if any, decolorizing action. Lime reduces the fire-shrinkage especially if present in large amounts, or over 3.0 per cent, and in very high lime clays and shales the fire-shrinkage is almost, if not quite *nil*. In fact the Aldrich shale with 11.08 per cent CaO and 7.84 per cent MgO actually expands or swells 1.0 per cent after burning (the average of eight carefully burned samples); while the Mayview clay with 9.9 per cent CaO (partly as carbonate and partly as silicate in feldspar) and 2.7 per cent MgO shrinks only 0.8 per cent, though under normal conditions the shrinkage should exceed 8.0 per cent. This counteracting tendency of lime when present as carbonate is due to the formation of quicklime, by the driving off of the carbonic acid at a red heat, and which by its swelling more or less neutralizes the shrinkage of the clay particles.

Clays, as the Aldrich shale for example, which are very high in carbonate of lime or magnesia pass very suddenly on heating from a soft, underburned condition into complete fusion without going through the very gradual transition that normal clays follow in slowing con-

tracting, growing denser, harder, stronger and gradually passing from a non-vitrified to a vitrified condition and finally to a very viscous state as the temperature is raised through a range of 300° to 600° F. The Aldrich shale passes from a soft, porous, unvitrified condition into a fused mass within a range of 50° F. (or from 2,175° to 2,225° F.), as also does the Barrett shale, which has 8 per cent CaO and 4.16 per cent MgO as carbonates. This rapid formation of silica of lime, by the free silica combining with the quicklime has been also noticed by Seger.* Such very high lime (as carbonate or sulphate) clays and shales by themselves would be worthless for any application in the plastic arts, as the ware made would be too soft and tender when burned at the usual temperatures, while they pass too rapidly into a state of fusion if the heat is raised but slightly higher, if the attempt is made to harden and strengthen them by raising them to the vitrifying point. Even when the lime and magnesia exceed 5.0 per cent (as carbonate) their weakening action is felt, and they have no such strengthening action as the alkalies, when the ware is burned to incipient vitrification.

Magnesia is found in almost all clays and shales, and ranges from a mere trace to 7.84 per cent in 112 Missouri samples. It occurs as:

(1) Silicate, in mica, chlorite and hornblende;

(2) Carbonate, in dolomite, and

(3) Sulphate, in epsom salts.

1. In most clays and shales the magnesia contained is in the form of the mica group of silicates, most of which have considerable amounts, or the chlorite group, which are all rich in it. The mica is usually seen as small thin spangles of insignificant thickness and of various colors, though most frequently of either a bright, light yellow or dark color. The chloritic group of minerals is seldom distinguishable by the eye, except by a more or less greenish tinge that is imparted to the clay, if not masked by the presence of too much organic coloring matter (which latter gives dark blue or black colors). The green shales are especially prone to be high in magnesia from this cause. A few other magnesian silicates are also liable to be occasionally found in clays, as the hornblende-augitic group and talc, though they are not usually of much importance.

2. Magnesia is occasionally present in shales, and less frequently in clays, in the form of dolomite, or the double carbonate of lime and magnesia. It is usually so finely disseminated throughout the mass as not to be distinguishable by the eye, though occasionally it segregates out as crystals and concretions that are usually white to yellow to

*Thonindustrie Zeitung, p. 197, 1888.

pink in color. Cold, dilute hydrochloric acid does not affect dolomite. When warmed or boiled it dissolves with effervescence, giving a colorless solution.

2. Magnesia sometimes occurs in clays and shales, especially those containing pyrite, as sulphate or epsom salts. This is a very soluble white mineral with a very bitter taste, and hence can be readily detected. Such clays on drying are more or less freely covered with an efflorescence of delicate, white, acicular or needle-like crystals or hairs which quickly dissolve on the tongue with a bitter taste. The soluble sulphate of the alkalies, potash and soda, also form these white incrustations, but are almost tasteless, while sulphate of lime, which also does this to a very slight extent, is practically insoluble in water. This formation of white incrustations on dry clays and brick-work, especially after the latter has been laid in fresh mortar, is popularly termed "saltpetering," from the erroneous notion that it is saltpetre or nitre, which is never the case.

Magnesian sulphate can readily be removed by leaching. Its origin is generally due to oxidation of pyrite and the action of the sulphuric acid thereby set free on the magnesian minerals present. Magnesia very much resembles lime in all its chemical properties, and its action as a fluxing agent is about as severe. In fact, the lime and magnesia are generally added together and considered as one base in the consideration of the fusibility of clays. What has been stated in regard to the maximum amounts of lime allowable in fireclays is applicable also to magnesia, or the two together. Such superficial rules, however, are at best but approximate on account of not only a probable slight difference in the actual fluxing value of magnesia being less than that of lime, but also for reason of a marked difference in the fluxing value of the different magnesia minerals, a fact that is never considered or given in a commercial analysis.

Magnesia probably has a bleaching or decolorizing action similar to that of lime, in clays containing coloring quantities of iron. The Missouri samples are not of such composition as to positively enable this statement to be proved. When present in large amounts it also probably has the same action as lime in tending to reduce the fire-shrinkage, though it must be remembered that fineness and the kind of grain are always more potent factors in affecting the amount of fire-shrinkage than chemical composition, unless the amount of the lime and magnesia is abnormally high, 5.0 per cent, or over.

UNUSUAL IMPURITIES.

Alum. The hydrous sulphate of alumina and potash, or alum, is occasionally found in some shales, less frequently in clays, containing pyrite. It results from the decomposition of the latter. It can usually be detected by its sweetish, astringent taste, and is sometimes visible as a white efflorescence. It is occasionaly found in sufficient amounts in shales to pay for its extraction by leaching, especially if the clay is first roasted and then weathered to further decompose the pyrite. It is decidedly objectionable in refractory clays as it renders them more fusible. It tends to produce blistering in potters' clay, from the evolution of the sulphuric acid at a high temperature. Fortunately it is not of common occurrence and it can be remove by leaching, being readily soluble in water.

Manganese, as the black oxide, has been found in one or two Missouri clays in trifling amounts, but unfortunately not in sufficient quantities to make a good slip clay. It is extremely objectionable in refractory clays, even more so than the alkalies, from its strong fluxing action, and for that reason it is very desirable in the special kinds of clays that are used for slip-glazing, or for forming the fusible enamel that enables earthenware to hold water.

Other minerals are often found in clays that are of vein origin, as the sulphides of the other metals, arsenides, phosphates and silicates, all of which have a more or less fluxing action and hence are objectionable in refractory clays. Some of them occasionally have a coloring action (copper and chromium) on both the raw and burned clay. But they are so exceptional and local in their occurrence that they cannot be considered in the general discussion, and none of them appear to be present in Missouri samples. Amber (or mineral resin) has been found as a few scattering nodules by Cook in some of the dark Woodbridge, N. J., clays, but only in specimen quantities.

VALUE OF CHEMICAL ANALYSIS OF CLAYS.

The importance of the chemical analysis of a clay is greatly exaggerated by chemists from a failure to use and work the clays analysed; while its value is not sufficiently appreciated by the potter and clay-worker, who prefer to get their information by the much more reliable method of actual trial. There is a universal idea that the refractory value of a clay can be readily inferred from the analysis, and the color of the burned ware predicted therefrom; but the work on the Missouri clays, which is one of the first cases, if not the first, in which analysis has been combined with reliable pyrometric determinations, shows

that for even these general applications an analysis must be used with caution and discrimination, and seldom suffices to completely answer these very important questions.

As regards fusibility the two foremost factors are density and fineness, the latter of which is never considered, while the former, though recognized, is not given the importance it deserves, and hence is not usually determined. As to the detrimental or fluxing impurities of a clay, it may be said that while it is true in general that the greater quantities in which they occur the more fusible is the clay, the fluxing agents differ so in their mode of occurrence, with a consequent greater or less variation in the intensity of their fluxing action as well as amongst themselves, that great caution must be used in weighing their values, and only approximate limits put on the allowable amounts. With two clays of similar density, fineness, and character of impurities the relative amounts of fluxing impurities will give a very reliable index of their respective refractoriness; but if the clays differ in fineness, density, and character of the fluxing impurities the chemical analysis must be used with the greatest care and positively endorsed by a pyrometric test. This is well illustrated in the very fine-grained, light (specific gravity 2.03), Commerce potters' clay which has only 3.56 per cent of fluxers, yet fails at 2,350° F., while the coarse, dense (specific gravity 2.45) Laclede fireclay, with 6.30 per cent of fluxers, does not fail until heated to 2,650° F.

If a clay is fine and contains less than 2.0 per cent of fluxing impurities it would be perfectly safe to predict the refractory character of such a clay, immaterial as to its fineness, density, or character of the fluxers; while if it has over 7.0 per cent of fluxers (alkalies, lime, magnesia and iron) it would be as decided evidence as to its non-refractory character, as such an excessive amount would ruin even the densest and coarsest clay. Between the limits of 2.0 and 7.0 it would not only be necessary to consider density, fineness and character of the fluxers in predicting the refractory value of a clay, but the positive evidence of the pyrometer would often be required to confirm even such a carefully formed decision.

In a china, or potters' clay, the presence of large amounts of alkali (especially potash) together with the absence of iron and magnesia, would strongly indicate feldspar, which would enable it to be burned at a lower heat (with consequent fuel economy) and insure a strong body to the ware.

In clays for vitrified ware, as paving-brick, the presence of large amounts of the alkalies and iron would insure fusion at a low temperature, and a strong ware if abundance of the former were present.

A chemical analysis sometimes gives positive evidence, and usually indicates the color to be expected of a clay when burned, though occasionally it totally fails. If a clay is free from iron or other oxides it is safe to assume that it will burn to a white color; if the iron is low (under 1.0 per cent) and there is considerable lime (over 1.5 per cent) it is probable that it will burn white, on account of the decolorizing action of the lime, which will be the stronger as the lime increases. For colored ware, as terra cotta, tiles, common and fancy brick, the depth of color will generally be the more marked as the percentage of iron increases, unless counteracted by lime, or combined as a silicate, in a granular condition.

A chemical analysis will also often give a clue as to the fire-shrinkage, for if the silica is very high (over 6.0 per cent) or the lime very high (over 3.0 per cent) the shrinkage is likely to be considerably less than if these were low, though the size and kind of grain are the most potent factors in influencing this property.

If an analysis shows a clay or shale to be very high in lime or magnesia (over 8.0 per cent) there is likely to be great difficulty in burning, as it is liable to pass suddenly from a soft to a fused condition; while the ware is liable to be weak and tender. If a clay contains much sulphate it is liable to cause blistering, as softening takes place as the acid is expelled.

A chemical analysis is therefore a valuable guide as indicating the purposes for which a clay can or cannot be used; but it must always be supplemented by physical tests to determine this extremely important property of plasticity (for which an analysis is totally valueless), to determine the question of air and fire-shrinkage, the ability to stand rapid drying, heating and cooling without cracking or crazing, and to positively determine the questions of strength, color, and fusibility.

CHAPTER IV.

PHYSICAL PROPERTIES OF CLAYS.

The physical properties of clay are by far the most important factors in its application in the arts, and as this is not always appreciated or thoroughly understood, the subject has been liberally amplified in order to show their influence and importance. In discussing its value the scientist and chemist lay too much stress on the chemical composition of a clay, whereas this should only be considered after the physical properties have been completely determined. Clays that are favorably adapted for a given purpose often show wide variations in chemical composition. In the case of two clays with about the same composition one may be very valuable for many purposes, while the other has only a very limited use. Thus, potters' clay may have a wide range in the percentages of silica, alumina, water and the alkalies and yet be very satisfactory, whereas the clay from the weathered portion of the flint-clay banks of Missouri has a very wide application for an excellent grade of china ware, potters' use, refractory material and terra cotta; while the material from the lower portion of the same bank, and having the same composition, can only be used to a limited extent as a "grog" in refractory ware, because it lacks plasticity.

THE PHYSICAL FACTORS.

The properties of a clay the market value of which is to be determined should first be examined, physically, and then supplemented by an chemical analysis, to round out and complete a knowledge of the sample. The properties which make up the physical structure of a clay, and which are taken up and individually discussed, on account of their very different values, according to the purposes for which the clay is to be used, are as follows:

Structure.
Hardness.
Odor.
Taste.
Feel.
Color.
Slacking.

TASTE.

When dry clay is touched by the tongue it usually adheres quite firmly, on account of its finely porous nature. On crushing the clay between the teeth an excellent idea can be obtained as to its plasticity by the greater or less readiness with which it sticks, as a "fat" or plastic clay adheres quite tenaciously, while a "lean" or slightly plastic clay does so but feebly. If there is grit or sand present it is easily detected by the teeth, giving an approximate idea as to the size and quantity of sand grains. Should alum, epsom salts, sulphate of iron, or other soluble impurities be present in the clay, they also may be detected by the taste. Hence, one of the first field tests made on a clay is to try a piece in the mouth, to give a rapid though crude idea as to its fineness, plasticity, grit, and possible presence of soluble salts.

FEEL.

Most clays when mixed with water to a plastic mass have an unctious or greasy feel, which is usually the more marked the finer and purer the clay; some very pure kinds, as the flint-clay, totally lack this unctious feel as they are non-plastic. By the sense of touch the coarseness or fineness of a clay can be roughly determined, as also the presence of coarse sand and grit. The most important physical property of clay, or its plasticity, can also be roughly determined by the feel or behavior on working the wet clay in the hand, and this is the manner in which this very valuable factor is determined by the trade. A plastic, tough, or "fat" clay will stand excessive moulding and distortion by the hand, without cracking, whereas the slightly plastic or "lean," or "short" clays crack and break more or less under such treatment. The feel is therefore a very valuable rough field test and with moderate experience it is easily and quickly acquired.

COLOR.

The color of clay after burning is of the greatest importance as regards the value and use of a clay, as on this question largely, if not entirely, depends its attractiveness for the higher classes of ware. Even in the lower grades of clay ware the sale of the goods is largely influenced by the color, though this may afterwards be of little importance in actual use, as for instance in sewer pipe which is usually placed under ground.

Clays vary greatly in color, both before and after burning. Except in some of the white clays the natural color is nearly always changed in burning. The natural colors range from white to various shades of

gray, drab, black, bluish black (called "blue"), green, yellow, red and brown. There is always a marked difference in the shade of color in a raw clay, according as it is wet or dry, as the colors are all deepened by wetting and lighten on drying. This difference is so marked as to often make it difficult to recognize the clay under the two conditions.

The colors of burned clay range from white to cream, buff, gray, orange, red, brown, purple and black; and if not homogeneous the colors may be mottled, streaked or clouded. The clays that burn white are used for the highest grades of ceramic ware or porcelain, white-ware and encaustic tiles. If they burn to a slight cream, or have a tinge of yellow, they are used for the inferior ironstone ware that is known as "C. C." ware. If the burned clay has a decided cream or buff color, it will not answer for white ware, but is desirable for stoneware, terra cotta and ornamental brick, for which purpose the dark buffs are also used. The reds are the favorite colors for brick, terra cotta and tiles, while for paving brick and sewer pipe the darker the color the more salable the goods. All of the various colors of natural or unburned clay can all be reduced to three classes:

(1) The white, in which the clays are usually free from coloring matter;

(2) Those in which the clays are more or less colored by organic matter, including the grays, drabs, blues, blacks and rarely the reds; and

(3) The iron-colored, in which according to the amount and condition of the iron, there is a variation from green to yellow, red and brown.

In a few rare instances, manganese is the coloring matter in brown and black clays.

1. The white clays are free from the usual coloring agents, organic matter and iron, and they therefore usually remain white after burning unless burned very hard, when, especially if they contain much titanium, they become more or less purple. As pure kaolinite is white the white clays are properly regarded as being very pure, but this idea is not well founded as they are liable to be as impure as other clays except in coloring matter. White clays are the scarcest of clays as the primary feldspathic rocks from which all clays were originally derived, nearly always contain more or less iron minerals (augite, hornblende, biotite, pyrite and magnetite). Should the parent rock be free from iron, which is exceptional, the clay may be contaminated by organic coloring matter, either in its journey to its place of deposition, or from the growth and development of aquatic plants that root or

drop down into it, before covered with fresh sediment. The most abundant variety of white clay is kaolin, which is generally found at its point of origin *in situ*. It usually has had no opportunity to become contaminated with vegetable or other organic matter. Some clays that are white before burning are found to contain iron minerals, often as disseminated grains that give a black spotted appearance to the burned ware.

The organically colored clays are usually thoroughly and homogeneously tinted by vegetable matter that is disseminated through the clay in a very fine state of division. If present in very small amounts it gives light gray to drab, rarely red colors; if present in large amounts the clay is very dark, and from slate-colored through black to blue in color. This organic matter is harmless in itself and burns out without detriment to the clay as it seldom amounts to 3.0 per cent and is usually less than one-third of this percentage. It masks the color of the burned clay which cannot be predicted safely from the raw material. All organically colored clays must therefore be burned to find out the resulting color, as there is liability to be coloration from white to buff, gray, orange, red, brown or even black. The iron salts, according to amount and condition, are the usual coloring agents of all burned clays and are often present in large amounts, but their presence is frequently masked by the dark vegetable matter.

The iron-colored clays are greenish, if the iron is present as the lower or protoxide form, and brown to yellow or red, if present in the higher or sesquioxide condition. The deeper the colors the more iron there is present, and the darker the resulting reds, blacks, or purples after burning (except when the unburned clay is colored red by vegetable matter). Sometimes the iron is present as pyrite in disseminated crystals or nodules, in which case it gives a black spotted appearance to the clay after burning. When the iron is present in the protoxide form (greenish to bluish) the clay burns dark to black when the kiln is run with a smoky reducing flame, but if the kiln is run with an oxidizing flame or with an excess of air, especially during the water-smoking, the resulting colors are red to brown, or the same that results when the iron is in the form of sesquioxide before burning. While as a rule the more iron there is in a clay, the deeper is the resulting red color after burning in an oxidizing atmosphere, there are modifying conditions, especially in the presence of lime and magnesia, that result in exceptions. Generally from 3.0 to 5.0 per cent of oxide of iron give a fine red color to clay that is burned with an excess of air; but if lime and magnesia are high, or over 5.0 per cent it saddens the color, and if the latter are present in very large amounts (or from 8.0 to 10.0

per cent) they neutralize the iron color completely and give a very dirty cream hue to the burned clay.

The question of purity or depth of color of the burned clay can be often predicted from the color of the raw clay if the latter is white, green, yellow, brown, or red; but if it is colored by organic matter, or is gray, drab, blue, or black, the color of the burned clay cannot be predicted from that of the raw clay, and an actual burning test is necessary.

SLACKING.

All clays and most shales possess the property of "slacking" or "dissolving" as the clay-workers often call it. When a piece of air-dried clay is immersed in water it more or less rapidly begins to slightly swell, then to crack and break up into fragments and these fragments subsequently into grains or flakes of small size. The finer clays are subject to disintegration into very minute grains, and from the surface inwards as the layers or films of fine particles keep falling off, expose new surfaces to the disintegrating action of quiet water. It is this property which causes the deeply rutted country roads and the big clods of the newly plowed field, after drying into a hard, strong "adobe" or dry mud, to soften and "melt away" to a uniform surface when wetted by a heavy rain storm.

The very hard, non-plastic "flint" clays only partly crack up into coarse angular granules, and very slowly. Ten to thirty minutes are required for an inch piece to break up into one-half or one-fourth inch fragments, with no fine granular disintegration whatever. The hard, strong clays of the coal measures which look to be almost as resistant as the "flint" clays, very quickly crack up and disintegrate into fine grains, taking only two to ten minutes for an inch cube to pass into a cone of fine powder. The china clays and kaolins, as also the loess or brick clays, "slack" or disintegrate even more rapidly than those last mentioned. The shales usually slack less rapidly and not so completely. They also have a tendency to break up into coarse flakes or scales rather than fine grains. To produce slacking it is necessary that the clay or shale be air-dried. If damp or wet, water fails to cause disintegration.

The property of slacking usually gives an excellent method of quickly arriving at a crude idea of the relative fineness of clays, as the disintegrated grains are from one-tenth to one-thirtieth of an inch in size in coarse clays; from one-thirtieth to one-sixtieth of an in inch in medium clays, and from one-sixtieth to one two-hundredth of an inch in fine clays. As the "flint" or non-plastic clays only crack up into

coarse fragments this method gives no idea of their fineness of grain.

The practical bearing of the property of slacking is of great importance in washing clay, or freeing it from coarse mechanical impurities. If a clay is sufficiently dry to slack readily by immersing in water, the fine clay particles disintegrate and in stirring are caught up and held in suspension by the moving water, while the coarse impurities settle and collect at the bottom of the washing tub. After the clay is "dissolved" or slacked, the water carrying the fine clay particles in suspension is run off into settling vats or ponds, while the sand and iron concentrates are left behind in the bottom of the washer.

Another important matter that is based on slacking action is the weathering of clays, or their continued exposure to the air. The main benefit that clays derive from weathering is primarily based on the separation of the lumps of clay into fine particles from alternate wetting and drying, which enables the soluble impurities to be reached and washed out by rains, while it also facilitates the rendering of the clays more homogeneous and plastic.

HOMOGENEITY.

There are very fine clays that in color, grain, chemical composition and plasticity are perfectly homogeneous as they occur in the bank. This fact is of great importance in making the finer grades of ceramic ware, as lack of homogeneity causes cracking or checking in drying and burning, produces irregularities in the shrinkage, with the consequent risks of distortion, causes mottling or spotting or graduations in the color, and more or less seriously interferes in the moulding by causing bad work and a damaged product. The variations in the homogeneity of different clays differs indefinitely from those which are perfectly homogeneous to those that are a series of thin layers, each of which has different properties and constitution.

For the coarser grades of clay ware, as brick and draintile, the rough mixing that is obtained in a tempering pit or pug mill suffices to overcome the sharp differences in the homogeneity, and to permit manufacturing with more or less success. If more thorough mixing is desirable the wet pan is preferable as the clay can be retained indefinitely, so that a very thorough mixing can finally be secured if kept long enough in the pan. This method of mixing is adopted for terra cotta, sewer pipe, roofing tiles and fire brick. For a more perfect mixing washing is resorted to, wherein the action of the blunger secures a very thorough mixing that is necessary for the highest grades of clay ware, or white-ware, encaustic tiles and porcelain. Weathering a clay partly neutralizes the lack of homogeneity but its main advant-

age is in so breaking up the particles as to admit of easy and thorough mixing when worked in a pug mill, wet pan, or blunger.

STRENGTH.

Clays and shales have a strength when in the condition of mud, that is not met with in other minerals; they have a strength when dried that is nearly equal to cement, and when hard-burned they have a crushing strength that is only exceeded by the toughest granites and metals. When clay and shale are finely ground and then mixed with water to a stiff mud they have sufficient strength to permit rolling out into sheets. The material is then utilized in making plates, is forced through a die as thin tubes, or pipes, or is forced through a die forming a bar which is cut into lengths, and the blocks piled on top of one another six to eight high without crushing or yielding. The mud has not only the coherence that any fine material has when mixed with water that is due to the adhesive force of the latter, but there is an interlocking or interlacing of the particles which enables them to be thus worked into thin sheets, pipes, or bricks without cracking, crushing or tearing, as would happen with fine sand or non-plastic substance. This toughness of the mud of clay requires considerable force to work it on account of this interlocking action of the particles, which is well illustrated by the power required to drive a wet or mixing pan which takes from 20 to 40 horse power, or in making brick on the large stiff-mud augur machines which require from 25 to 45 horse power. While there is also much external friction to overcome in the last two examples the greater portion of the power required in working the wet pan or brick machines is probably the internal work of overcoming the interlacing of the particles of clay. This toughness of the mud which is very intimately identified with the plasticity of the clay is the basis of the ability to mould and form objects of clay; and the strength that the ware possesses after the water is dried out enables it to be safely handled and piled up in a kiln preparatory to burning.

Dry clay after being moulded from a stiff mud is found to have a tensile strength, or to resist a pull, that varies from 20 to 100 pounds to the square inch in lean clays, from 100 to 200 pounds in ordinary plastic clays and from 200 to 400 pounds in very plastic clays. This last is remarkable, as it nearly equals the high strength of Portland cement, in which the strength is due to the formation of a new chemical compound crystallizing from the mixture of sand, water and cement powder. As the strong, dry clay softens or "dissolves" or "slacks," when covered with water, into a fine pulverant mass and as this mass when worked into a mud again dries into a strongly coherent mass

with the same high strength, this strength is due purely to mechanical action, without the aid of crystallization from chemical changes as occurs in the cement, and hence is due to an interlocking action of the clay particles. The interlocked particles are liable to move or slide over one another when wet, or as a mud, from the lubricating action of the film of water between them; but when this water dries out and the grains can no longer move without rupturing the bond the high strength of the dried clay results. The strength of the mud and the dry clay is closely related to the plasticity, and, as the two properties seem to be based on the interlocking of very thin plates the strength of the dry clay, as determined by breaking air-dried briquettes that have been moulded from a stiff mud was used as an index or relative measure of the plasticity, as explained under that head.

When the dry clay is burned its strength is found to increase as the temperature is raised, and when the clay is brought to the point of incipient vitrification it has a high tensile or cross-breaking strength, and a very high crushing strength. When it is completely vitrified the maximum strength is attained, and is found to range from 1,000 to 3,300 pounds in cross-breaking for each square inch of cross section, and from 4,000 to 30,000 pounds crushing resistence to the square inch. The usual range of resistance of good paving-brick to crushing is from 10,000 to 20,000 pounds a square inch, equal to the strongest of the building stones as marble, trap, limestone and granite.

SPEED OF DRYING AND BURNING.

There is a very marked difference in the speed with which different clays and shales can be air-dried and subsequently burned in a kiln. This has a very important influence in the successful working and economy of a clay. It is popularly supposed that a clay which must be slowly dried must also be slowly burned, but it is found, as shown below, that the property which enables a clay to be rapidly dried is quite different from that on which depends its ability to be rapidly heated, so that each must be considered separately.

Some clays while in the condition of a soft, plastic paste can be exposed immediately after moulding to the wind, to the heat of the sun, or to the heat of a drying chamber and be rapidly dried without checking or cracking, if care is taken that the object dries out equally on all sides, without warping. Other clays, on the contrary, need a very long time and the greatest care in drying, to avoid checking and cracking, and warp rapidly if perfect uniformity in drying is not secured. There is a very great range in the speed with which different clays part with water of plasticity in air-drying without cracking. A

few very coarse and very lean clays, when made into a brick, can be dried out in the very short space of 12 hours, while very fine, very plastic, "strong" clays need from a week to ten days, and a few "very strong" clays require a still longer time.

On studying the cause of this very great difference in the drying speed it is found to be physical and to be due to relative plasticity, since the less plastic the clay is the faster it can be dried out, while the more plastic it is the more slowly must it be dried to avoid cracking. As plasticity seems to depend on the eminent development of a fine scaly structure, the cause for this variation in drying seems to be partly due to the fact that the plastic clays usually have much more water to dry out than lean clays, but mainly to the fact that the interstitial spaces and capillary tubes that convey the water from the interior surface are so minute and irregular as to prevent the inner water from escaping as fast as it dries on the surface. Hence, the outer portion drying faster than the inner, and therefore shrinking more rapidly, must necessarily pull apart, or check and crack more or less, and the depth of the cracking will be the deeper as the rates of drying between the interior and the surface differ. Therefore, to avoid cracking, the outer portion must not be allowed to dry out faster than the capillary tubes can convey the water from the interior, and hence the drying must be delayed. The more broken the capillary tubes from the interlacing of the scales or particles of the clay, the more time must be given to them to slowly bring the interior water out to the surface.

The practical importance of the rate in air-drying is very great as regards the economic working of a clay. A slow-drying clay calls for a very much larger drying area for a given daily capacity, with the increased cost of construction, maintenance, and extra handling; there is a much larger stock of goods locked up in the various stages of drying; there is a greater risk of breakage in having the goods exposed so long in the tender condition of drying; while much greater care has to be taken to avoid draughts or variations in the temperature. Rapid-drying clays permit the use of drying floors, drying chambers, or drying kilns, without the risk of cracking the ware, with a great saving in time and regularity of work that this permits, as against the dependence upon air-drying, with its great fluctuations in rate due to change in temperature and humidity.

To hasten the speed of slow-drying clays one of the safest and simplest methods is to mix it thoroughly with a lean or coarse clay. If the character of the ware is such as to make this undesirable, or if a lean, coarse clay is not accessible, the admixture with "grog" or

such lean material as sand, crushed quartz, burnt clay and crushed fire-brick greatly increases the speed in drying and also decreases the amount of shrinkage. Of these non-shrinking mixtures the best for the purpose of increasing the speed in drying is calcined clay or crushed fire-brick, which from the highly porous nature greatly facilitates the escape of moisture from the interior to the surface, and the more freely it is used the more rapidly it can be dried and the less is the shrinkage.

The objections to the use of "grog" is the fact that the more freely it is used the less is the strength of the burned ware, unless burned throughout to complete vitrification, as it has a decidedly weakening action in both the paste and the burned ware; while if the clay is moulded by machine, the "grog" is very severe in its abrasion or wearing action on the dies and moulds. By mixing with a lean clay instead of "grog," the latter objection is almost entirely removed, while the strength is but slightly affected if the mixing is thorougbly done, and in not too large amounts (over 60 per cent). In the use of either lean clay or "grog" for hastening the drying, the percentage used is generally adjusted to the thickness of the ware to be made, as the thicker the ware, the more freely it is used, often to the extent of 60 to 70 per cent in large furnace blocks. Twenty-five per cent is sufficient in the much thinner fire-bricks. Where the use of grog is inadmissible or in only small amounts, it is often necessary to retard the drying, in order to give the moisture time enough to come out from the interior, by covering the surface with damp cloths or wet straw, or to tightly shut up the room, so as to keep the air at or near its maximum humidity (when it has a very slightly drying power). Another method of retarding the drying to avoid cracking is to use salt in the water with which the clay is mixed into a paste. On account of the strong affinity of salt for water, this material decreases the rate of evaporation, but it can only be used in such applications as brick or sewer pipe.

In heating dry clays in a kiln up to a red heat there is found to be a very marked difference in the speed with which they can be heated, to avoid cracking until after a full red heat has been obtained when there is not near so great a difference. There is no such great range in the speed of burning different clays as there is in the air-drying, and the fact that it almost disappears at a red heat when the chemically combined water has been expelled, shows that it is partly due to chemical, and partly to physical causes.

In considering the different kinds of clays and shales it is found that plasticity or "strength," *per se*, has no direct influence on the speed with which a clay can be heated without checking or cracking. Some of the most plastic clays, which require very slow air-drying, can be rapidly heated; while many very lean or slightly plastic clays, which permit very rapid air-drying, must be heated very slowly. It is found, other things being equal, that the greater the amount of chemically combined water the slower the clay has to be heated, to give sufficient time for its expulsion and hence, as the purer the clay, the greater is the amount of water, the purest clays are the most prone to check, unless heated very carefully.

A second very important factor in the ability to stand rapid heating is the fineness of the clay, as the coarser the natural grain, the more rapidly it can be heated, while the finer the clay, the more slowly it must be heated to avoid cracking, other conditions being the same. This is probably due to the fact that the coarse-grained clays are much more porous or richer in large interstitial spaces than the fine-grained varieties. Hence there is room for the differential expansion and contraction of the grains as a clay is heated (or cooled) which must arise from the poor conductivity of clay. The fine-grained clays do not have room for the expansion of the grains on the outer and hotter portion of the ware, on account of its much closer structure and therefore pull apart, shell off, or burst open from the cooler inner portion expanding (or contracting) more slowly. This is verified in practice, as the denser a clay is made in moulding, by the use of heavy pressure, the more slowly the same clay must be heated to avoid checking or cracking.

A third factor that affects the speed of heating, though it is of much less importance than the others, is the kind or character of grain. In a few cases it is found that the percentage of water and fineness of grain were so nearly alike as to expect certain clays to show equal speed in the rate of heating, but there is sufficient difference to indicate that the character of the grain has also an influence. If the grains are strongly interlocked by a fine plate structure it possesses a strength that resists the expansion strains; whereas a clay, in which the fine plate structure is feebly developed, is ruptured, on account of the feeble cohesion of the grains. It is found that the plastic clays stand rapid heating, whereas slightly plastic clays do not, indicating that the same fine plate structure that gives plasticity to the clays also gives them the strength to bear rapid heating.

The speed of air-drying is very intimately related in an inverse ratio to plasticity, and therefore is inversely related to the amount of shrinkage. There is a similar tendency for the speed of heating to be

inversely as the amount of shrinkage, but as the question of fineness of grain is even more important than the amount of chemically combined water that is expelled and as the character of the grain has some influence there are frequent exceptions to the rule, so that some very fine-grained clays, which shrink only 1 to 4 per cent in burning, have to be heated very slowly, while some coarse-grained clays that shrink as much as 7.0 to 9.0 per cent can be heated rapidly without checking.

In the cooling off of hot clays, after burning in a kiln, there are the same conditions as in heating as to fineness and kind of grain in influencing the rate at which it can be cooled down, and the fireclays must be allowed to cool slowly, while the coarse varieties may be rapidly cooled without cracking or checking. The other factor, the chemically combined water, is eliminated from the cooling, but the others are as potent in the speed of cooling as in the speed of heating.

DENSITY.

The density, specific gravity, or the relative weight, of clays and shales differs considerably. It is mainly a physical question, though in a few cases the chemical compositon enters to some extent. The principal impurities of clays are sand and feldspar, but as these have a specific gravity of 2.55 to 2.75, while pure kaolinite is 2.60 to 2.63, they do not appreciably affect the results. If iron minerals are present in any quantity they materially increase the weight of the clay, as they range in a specific gravity from 3.8 in siderite (which is very common in the coal measure shales of Missouri) to 4.0 in limonite (which gives the yellow to brown color), to 5.1 in pyrite, which latter is very frequently present in small amounts in the Missouri fireclays and shales.

The principle factor that has influenced the density of clays is the pressure or weight that they have been subjected to since they were originally deposited. Thus, the Missouri kaolins, which are found *in situ* or have been transported but a short distance, and have had but little if any thickness or cover over them, range from 1.69 to 2.02, and average 1.90 in specific gravity. In consequence of this lack of any weight on them, they are generally very soft and tender, and can usually be easily worked by a shovel or sharp spade direct from the pit. Similarily the Missouri loess clays have had no overlying beds, as they were deposited during the most recent geological periods. They range from 1.69 to 2.17, and average 2.05. The gumbo clays, which are the silts of the present rivers, and hence are the top formations, range from 1.98 to 2.05, and average 2.01. Both the loess and gumbo clays are so soft and friable that they are worked with a pick, plow and shovel. The potters' clays and fireclays of Missouri are mostly from

the coal measures and have usually been overlaid by several hundred feet of other rocks. They range from 2.23 to 2.54, and average about 2.40. They have a hardness from 2.0 to 2.5, are very firm and rock-like, when not weathered, and require blasting to economically work them in mining, though they can be cut by a sharp pick but with much difficulty. Some of the more recent clays of Tertiary age range from 1.93 to 2.13, and they are much softer and easily worked.

The "flint" or "non-plastic" fireclays occur in pockets in Paleozoic limestones and they are remarkable for their hardness, their conchoidal fracture, and great purity. They have a high density ranging from 2.10 to 2.45, with an average of 2.38. The shales have all been subjected to considerable pressure and they have a high density as a rule, as they range from 2.15 to 2.56, averaging about 2.38.

Washing diminishes the specific gravity of clay, as the particles can never be consolidated under the moderate pressure of the filter press to the extent that the great and constant pressure of many hundred feet of overlying rocks gives. This is well shown in the St. Louis fire-clays, which range from 2.40 to 2.47, and average 2.44; these same clays when washed only have a specific gravity of 1.92 to 2.13. The Jamison washed clay which is settled and air-dried in shallow tanks under a pressure of only 1 to 2 pounds, has a density of 1.92, while the Christy washed clay which is subjected to a pressure of 100 pounds to the square inch in a filter press, has a density of 2.13, which also illustrates the consolidating action of pressure.

The density of a clay has a very important bearing on its refractoriness. It is found that the denser the clay the more refractory it is, other things being equal. While this fact is generally known, its importance has not been appreciated, so that it is rare to see the specific gravity given with a clay analysis, though it is a very vital factor in the heat resisting power of a clay. The work with a pyrometer on the fusibility of the Missouri clays shows that for every increase of 0.20 to 0.25 in the density of a clay the fluxing impurities may be increased 0.5 to 1.5 without lowering the refractoriness, and as clays are liable to range from 1.50 to 2.50 in specific gravity it is impossible to correctly weigh the evidence of chemical analysis of a clay unless the density and fineness of grain are also given. The specific gravity should always be determined of every clay especially of the fire or heat-resisting varieties, and several samples should be taken to get a reliable average and also the variations due to chemical or physical differences. The specific gravities subsequently given of the Missouri clays were averaged from 2 to 8 determinations, though usually 3 or 4 samples were tested.

FINENESS OF GRAIN.

The fineness of grain of clays is a matter that has been largely overlooked by earlier investigators, though it is a factor of great importance in considering the fusibility of clays, and has a very marked influence on the plasticity, shrinkage, and rate of drying and heating. By the fineness of grain is meant the apparent fineness as evidenced to the eye, touch and feel, and which is more forcibly brought out when a piece of dried clay is slacked in water. In this last test, which is easily and quickly performed by dropping a fragment of perfectly dry clay in a glass of clear water, the clay more or less rapidly falls into a conical pile of particles that vary in size from one-fourth to one-twentieth of an inch in coarse clays; one-twentieth to one-fortieth of an inch, in medium clays, and from one-fortieth to one-two-hundredth of an inch in fine clays. It is by this method of estimating the relative fineness of grain that is here discussed, as this test is simple, rapid, effective, and can be made by anyone. The estimation of the relative fineness of the grain by mere ocular inspection or by feel requires experience, and is subject to a personal error that is liable to be large. The absolute fineness of the grain, as shown by the microscope, is found to vary between the great range of one-five-hundredth of an inch to one-two-thousandth. The values given by the microscope are after all only relative and have no intrinsic merit over the cruder but much simpler and quicker slacking method of determining the relative fineness. The molecular or absolute fineness cannot be discerned by the microscope, and it is only the groups of molecules that are detected and measured. Moreover, the microscope requires a scientific training and experience that few possess, especially among the clay-workers. The ability to use the slacking test can be acquired in a few minutes and its value for practical purposes is quite as great as the more refined and delicate microscopic method. It is for this reason that the subsequent remarks are based on the slacking method of estimating the relative fineness of grain.

Under "Fusibility of Clays" has been mentioned the influence of the fineness of grain on fusibility, and it is only necessary here to repeat that the finer the grain, other things remaining the same, the more fusible the clay is. Further, that of two clays with the same composition, but one having a coarse grain and the other a fine grain, there is liable to be a difference of at least 200° F., in their respective fusing points. This is keenly appreciated by the manufacturers of firebrick and other refractory ware, who are very careful not to grind the clay too fine, as they realize that the coarser the grain the more refractory the

ware is. This important influence has been seriously overlooked by chemists who have ignored this important physical factor as well as the equally important question of density, in attempting to determine the fusibility of clays by chemical formula, from their composition. The subject was not as thoroughly investigated as was desirable nor were clays occurring outside of the state examined but the general results were sufficient to prove a valuable guide to the practical worker.

The influence of fineness of grain on the plasticity of clays had been observed by early students on some of whom it made such a deep impression that to this one factor alone was attributed the cause of plasticity. But as already mentioned, plasticity cannot be attributed to fineness alone. The evidence seems to be overwhelming, when the matter is thoroughly investigated, that a fine plate structure is the cause of plasticity; and unless the natural coarsely laminated crystals of kaolinite are separated into thin plates there is little or no plasticity in clays. It follows as a necessary sequence in the splitting up and disrupting of the coarse lamellar crystals into thin plates and fine scales, that there must necessarily be more or less fine particles produced, and these fine particles have been mistaken for the cause, instead of the effect of plasticity. That fineness alone is not the cause of plasticity is well shown by the fact that if a clay is excessively pugged or over-worked it becomes "dead" or loses its plasticity. This shows that when the plates are broken to mere fine particles the plasticity is lost instead of being increased as would result if fineness alone were the real cause. As previously mentioned under "plasticity," it is furthermore found that minerals without a lamellar structure, no matter how finely ground, do not become plastic, whereas minerals with a natural lamellar structure, as gypsum and talc, become decidedly plastic when finely ground. As a broad rule, the finer the clay, the more plastic it is usually found to be, but to this there are many exceptions and notably among the kaolins. When these slightly plastic clays are examined under the microscope, it is found that the kaolinite is in coarse aggregates and not in a fine scaly condition, though to the naked eye it seems to be very finely divided. When the transported clays, as the glacial deposits afford, the loess, fire-clays, potters' clays and shales, exhibit a fine structure it is nearly always accompanied by eminent development of plasticity.

The fineness of grain is generally supposed to have a marked influence on the shrinkage and speed with which a clay can be dried and burned, as the finer the grain, the greater the shrinkage and the slower it must be dried and burned to avoid checking. This broad rule is found to have so many exceptions as to make it untrustworthy to ap-

ply and depend upon in actual tests. Many fine clays shrink excessively and require slow drying and slow heating, but other clays that seem by the slacking test to be equally as fine, exhibit only a moderate shrinkage, and can be rapidly dried and heated; while some coarse clays also require some care in heating and occasionally exhibit excessive shrinkage. In other words, there is a certain structure in the clay dependent on the character of the grain that materially affects this, and which seems to be independent of the fineness as judged by the crude slacking test. There is, therefore, only one way to determine the question of shrinkage and speed of drying and burning, that is, by actual test.

VALUE OF EYE ESTIMATES.

The estimation of the probable value and use of a given clay can be arrived at with considerable certainty in some cases when the requisite experience is possessed, while it is extremely inadvisable to attempt in most cases, no matter how great the experience may be. There is a tendency by practical clay-workers to give dogmatic values to a clay solely from an eye estimate, from more or less broad experience (usually decidedly narrow), but there are some clays that the most experienced clay-worker is liable to make serious errors with if he depends solely upon the meagre information that can be obtained by the eye. The color of clay is largely used in this crude, preliminary method, but as previously mentioned, the color is not always reliable for estimating the presence or absence of certain impurities, notably iron. While an excessively iron-stained clay is, to say the least, very discouraging for refractory purposes, yet there do occur very superior fire-clays that show apparently excessive amounts of iron, as judged by the liberal stains of sesquioxide. One of the best fireclays of New Jersey has a red color that would condemn it for refractory purposes, if organic matter were not the cause of the color, which burns out and leaves a buff-colored, highly resistent product. Again, a pure, white clay which is apparently so free from iron as to be serviceable for white ware may have so much titanium as to give it a bluish-purple color, which would bar its use for china ware. If such exceptions are kept in view the color can be frequently used with caution and discretion, to indicate the probable scope of the clay. The fusibility, shrinkage, speed of drying, burning and the color of the burned ware are questions that can only be safely and satisfactorily determined by actual test, and the great risks and uncertainties of attempting to guess at them by mere ocular estimates should never be attempted. The plasticity can be easily and quickly determined for practical purposes by the feel, in working to a paste a small amount of it with water.

MICROSCOPIC EXAMINATION.

The microscopic consideration of clays has received some attention from the various investigators, notably Johnson and Blake,* Cook,† Tenier‡ and Brackett and Williams§. It was hoped in the preliminary studies of the Missouri clays that much aid would be derived from a through microscopic study, especially as regards the mineralogical character of the impurities and the possible cause of plasticity. The ultimate analysis that is made by the chemist shows that the mineralogical character of most clays is complex; and this conclusion is confirmed by a careful inspection of damp clay, especially if the eye is aided by a good lens, and by panning. As the form of the combination of the impurities in clay has a marked influence on its fusibility such definite information is extremely desirable. This question would not only have an important practical bearing, but would greatly aid the chemist in arriving at a reliable estimate of the fusibility of a clay after the analysis has been completed. The cause of the plasticity of clays is a very important scientific problem. It was thought that in such a thorough investigation as was made of the Missouri clays, where complete physical tests were combined with chemical analyses, that positive light might be thrown on this subject.

Appreciating the desirability of a microscopic examination of the clays, Prof. Erasmus Haworth undertook the problem. While all the samples collected were not investigated, a very complete series was selected, especially those in which individual features called for special attention.

It was found in the course of the work that the usual thin slides were imperfect, as the soft clays had not sufficient strength to withstand the grinding processes, while the hard, flint clays that were capable of being thus treated lost the inclosed particles of sand. The method he adopted was to examine drops of clay suspended in water that was obtained by differential decantation, after the air-dried clays had been slacked in water. The hard flint clays were soaked in water, and crushed under a mortar, before being brought to a state of suspension in water. The lenses usually employed ranged from 400 to 600 diameters, though powers as low as 350, and as high as 1,000 were used.

Professor Haworth found that minute size greatly interfered with the determination of the mineralogical composition of the clay, as many

* Amer. Jour. Sci., (2), vol. XLIII, p. 351, 1867.

† Rep. on New Jersey clays, p. 287, 1878.

‡ Compte Rendus, t. CVIII, p. 1071, 1889.

§ Am. Jour. Sci., (3), vol. XLII, p. 11, 1891.

of the particles were found to be less than one-one-hundred-thousandth of an inch in diameter. Such common impurities as feldspar pyrite, magnetite, calcite, gypsum, alum, and lignite were not recognized.

Professor Haworth's studies on the plasticity of clays largely coincides with those of Johnson and of Cook, as he regards plasticity as being due to the extreme fineness of grains.

CHAPTER V.

PLASTICITY OF CLAYS.

Plasticity is that property which enables a clay, after being worked into a paste with water, to retain its shape after moulding. It is the most valuable property that a clay possesses and is the primary basis of nearly all its applications. A plastic clay when worked up with the proper amount of water to a soft paste, can be easily moulded either into the largest furnace blocks or the most delicate articles of ceramic ware, and the shape is perfectly retained with sufficient strength to bear the necessary handling until it is finally burned into a very hard, strong body by the high heat of the kiln. It is the only mineral substance that possesses this property to a noteworthy degree. Many organic substances, either singly or in admixture, possess this property at certain temperatures, as wax, tar, many resins, gums and sugars, but it is usually impossible to develop any marked strength, as they cannot be fired, though some of them may be rendered more or less hard and tough by chemical action, as celluloid and vulcanite.

The plastic clays are found to require certain percentages of water to develop the greatest degree of plasticity; with smaller amounts they are very stiff and difficult to work, and crack and break more or less in the process of moulding, but retain the shape perfectly after moulding; if too much water is used they work or mould very easily, but do not retain the shape after moulding, as they yield or droop on handling or standing. The amount of water necessary to be mixed with a clay to develop the greatest ease of moulding (without cracking), combined with sufficient stiffness to retain the shape perfectly, varies with different clays, according to the fineness and character of the grain, as the finer or more thinly lamellar the clay, the greater is the amount of water required. With the coarse clays from 14.0 to 20.0 per cent of water added to the air-dry material is sufficient to bring out the maximum plasticity; with the fine clays from 20.0 to 25.0 per cent is needed; while the very fine clays, as the kaolins, often require 25.0 to 30.0 and occasionally 35.0 per cent of water. The actual amount found necessary to develop a uniform degree of stiffness in

making up the Missouri samples was found to range as given below. It strikingly shows not only the individuality that every clay possesses, but the great variation in the fineness of the grain that is liable to be found in the same class of clays (working with air-dried samples).

Water required to Develop the Maximum Plasticity.

	Per cent.
Loess, or brick-clays	16.0 to 19.0
Fire and potters' clays	15.0 to 33.0
Flint clays	15.0 to 24.0
Kaolins	18.0 to 35.0
Shales	14.0 to 25.0

CAUSE OF PLASTICITY.

The great difference that exists in the degree of plasticity of different clays and the fact that clay is the only mineral that naturally possesses true plasticity to a marked extent, renders the question of the cause of plasticity a very important matter to both the student and the clay-worker. As a broad rule the coarse or sandy clays are less plastic than the fine or gritless clays, though there are many exceptions, notably among the kaolins which, though very fine-grained, are frequently only moderately plastic. All clays are rendered more plastic by grinding unless the process is carried on to a very excessive extent. This is best illustrated in the flint fireclays, for they are usually very feebly plastic as they occur in nature, but can be rendered tolerably plastic by fine grinding. Thus the Garstang flint clay, when ground to 20-mesh, was very slightly plastic, or tested only 25 pounds to a square inch by the tensile strength scale; whereas it was notably plastic when ground to 100-mesh, and then tested to 65 pounds, or was more than twice as plastic. In most of the applications of clay the more plastic it is the greater is its value, up to a certain point. As it permits of easier and more rapid working it allows of the admixture of larger quantities of spar, flint or "grog," and it makes a much stronger ware, both before and after burning. Hence a study of the cause and development of the property of plasticity has an important practical bearing as well as scientific interest.

THEORIES OF THE CAUSE OF PLASTICITY IN CLAYS.

Water Theory. The cause of plasticity is still a mooted question. Many different theories have been advanced to explain it, of which only the more prominent are given. One of the oldest theories attributes this property to the chemically combined water that all clays possess, because when this is driven off by heating the clays to a red

heat they are rendered non-plastic, and the plasticity cannot be restored if the burned products are subsequently finely ground. This last fact has made such a deep impression that many have accepted this theory without making further inquiry, though on investigation it is found wholly untenable. In the first place there are a very large number of other minerals that are hydrous silicates of alumina (both simple and complex) which have no plasticity whatever. This is notably true of the closely related massive mineral halloysite, a hydrous silicate of alumina, which has more water than kaolin has, yet it is devoid of plasticity. Again, some of the purest clays, notably the flint clays, with the highest amounts of water, or from 12.0 to 15.0 per cent, are very deficient if not entirely lacking in plasticity; while the gumbo clays which are the most plastic of all are very low in water, having from 7.0 to 9.0 per cent. Some of the loess clays, with only 5.0 to 6.0 per cent of combined water, are very plastic. The driving off of the chemically combined water at a red heat, when the clay suffers a loss of 5.0 to 15.0 per cent of its volume, causes such a series of physical changes accompanied by a complete breaking up of the former molecules, that radically new properties result as a diminished volume, greatly increased hardness and strength, usually a change in color, and loss of plastic properties. This change in all the physical properties by burning, has caused superficial observers to attach the most important chemical change as the cause of the plasticity. Instead it is the effect of conditions that have entirely changed the physical as well as the chemical nature of the clay.

Impurity Theory. Another theory attributes plasticity to the presence of certain impurities that act as flexible binders to the kaolinite particles. This is based on the fact that pure crystalized kaolinite is not plastic, while the most impure clays are the most plastic. Further, it is well known that alumina has a strong physical affinity for many substances, which become mechanically entangled in it in a very thorough manner, when it is used as a coagulent; while one of the most common impurities of all clays and shales is iron, which acts as a strong cement under certain conditions, and notably as the freshly precipitated hydrous ferric oxide, the condition in which it is probably introduced in the formation of most clay deposits. This theory has a more attractive foundation than the combined water theory, but is lametably unable to meet some very important objections. While the purest clays known, the Missouri flint clays, are usually only feebly plastic, they are found to be plastic at the outcrop, and change in depth to a non-plastic state, when beyond the action of frost; but no chemical change is found to have occurred and the plastic portion is

as pure as the non-plastic portion. Again, no minerals are known which naturally possess plasticity in themselves, and therefore, they could not impart plasticity if mixed with kaolinite. Alumina and iron are often strongly cementing substances under certain conditions, but they make rigid, unyielding binders that possess no plasticity. A more potent objection is the fact that many pure clays are also very plastic; and the statement that the most plastic clays are the most impure is only true in a very general sense, for there are many exceptions to the rule, and sometimes very impure clays occur that are only slightly plastic.

That many impure clays are very plastic, in spite of the presence of impurities, shows that the physical condition which causes plasticity is so eminently developed as to render the clay plastic, notwithstanding the diluting action of the impurities. Unless the foreign matter is present in a very large amount it is not found to seriously impair the plasticity, as is shown in the following experiment with a washed fireclay that has a well developed plasticity (Christy, St. Louis). This clay after washing contains 45.0 per cent of foreign matter, of which over 38.0 per cent is sand or uncombined silica. This washed clay was intimately mixed with sand that had been screened through a 20-mesh seive, in different proportions, and then worked into a stiff paste with the various amounts of water, giving the following results:

Effect of Foreign Matter on Plasticity.

Mixture.	Per cent of water used.	Tensile Strength.		Plasticity Ratio.
		Maximum.	Average.	
Clay	18.0	190	168	100
25 per cent sand	12.4	175	148	92
50 per cent sand	11.5	125	111	66
67 per cent sand	13 2	79	72	42

Remembering that the above clay naturally possesses 45.0 per cent of foreign matter, its plasticity was only reduced 8.0 per cent when mixed with 25 0 per cent more additional foreign matter, and 34.0 per cent when 50.0 per cent of sand was added; and when the dilution was so great that there was only 18.0 per cent of pure kaolinite (when 67.0 per cent sand was added) it still was moderately plastic, though possessing only 42.0 per cent of the plasticity of the original washed clay.

Alumina Theory. Another chemical theory is that plasticity is due to the alumina which is an essential constituent of all clays. The same objection holds true of this idea as in the case of the water, since there are clays both high and low in alumina that have both an eminent and a feeble plasticity.

As none of the theories that are based on chemical composition are liable to satisfactorily explain the cause of plasticity physical reasons have been appealed to for a solution of the problem.

Interlocking Theory. A physical theory for plasticity is based on an interlocking or hooked or possibly dumb-bell-like form of crystal, which would permit considerable freedom of movement, yet give ample strength to hold the moulded form. There are a few minerals, as prochlorite, which crystallize in interlocking aggregates, as in the accompanying sketch (figure 1), or again as in gypsum (figure 2) that would

Figure 1. Curved Crystal of Prochlorite.

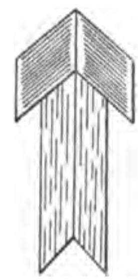


Figure 2. Interlocking Form of Gypsum Crystal.

furnish such conditions. This hypothesis is strengthened by the fact that Ternier* had described a mineral from the Carboniferous shales and in residual clays from eruptive rocks that occurs in vermicular aggregates. Haworth's work at first seemed to strongly endorse this theory, as he found the Missouri clays abounding in a mineral that had similar forms which he thought belonged to one of the chlorites. When magnified to 300 diameters, it presented a decidedly vermicular appearance, as shown in the accompanying sketch (figure 3). With higher powers the aggregates were found to be composed of thin plates, arranged as multiple twins, and to have a light greenish color by transmitted light. Further study showed that the clays which contained it in greatest abundance were the chinaclay from Regina (Jefferson county), pink kaolin from Sargent (Texas county), white kaolin from Glen Allen (Bollinger county), kaolin from the Buffalo mine (Pettis county), and kaolin from Sterling (Howell county). It constitutes

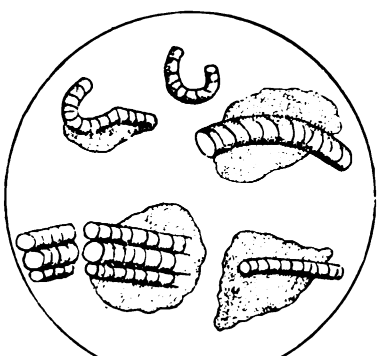


Figure 3. Vermicular Crystals in Clay, × 300.

*Compte Rendus, t. CVIII, p. 1071, 1889.

about ten per cent of the volume in some of these kaolins, but much less in others, according to Haworth. But it happens that in all the clays that were richest in these peculiar crystals the plasticity was not well developed; while in the clays that were eminently plastic such hooked crystals were not well developed or were absent, a fact which renders this theory untenable.

Fineness Theory. Another theory attributes plasticity to the fineness of the material, as the microscope usually shows that the individual particles are very fine, or from 0.001 to 0.0005 of an inch according to Johnson and Blake, and according to Haworth as fine as 0.00001 of an inch. This theory seems very plausible when it is considered that all clays are rendered more plastic the finer they are ground. But if fineness of grain is the sole cause, then plasticity should be developed in other minerals, if they also are finely ground. It is true that any substance ground very fine is somewhat plastic when mixed with a proper amount of water, or at least admits of being moulded; but such substances are only feebly plastic, and when the water dries out the particles cohere with such slight strength that they crush or fall to pieces on handling, instead of having the decided strength of a plastic clay which frequently exceeds that of cement. A quartz crystal that was ground to pass through a 100-mesh sieve, when the particles would be less than one-one-hundred and fiftieth of an inch in size, showed very slight plasticity; but when it was ground to 200-mesh or the particles were less than one-three-hundredth of an inch in size, it seemed to be appreciably plastic, though on drying the coherence was so slight that it required the gentlest handling to prevent the moulded sample from falling to pieces. A sample of air-floated dust, from a quartz vein that settled on the mine timbers (from blasting) and which was an impalpably fine powder, dried to a very tender mass, as did likewise the impalpable geyserite or finely precipitated opal (or hydrous silica) from hot springs. The very fine form of silica known as "tripoli" which results from the breaking up of chert by weathering, when ground to an impalpable, gritless powder was quite plastic when wet, but possessed but slight strength when dry. When compact limestone was ground to 100- and 200-mesh, it could be moulded with great ease when wet and would be rated as "very short," but on drying the cohesion was very feeble. Yet the Missouri clays and shales, the tensile strength of which was found to range from 10 to 400 pounds for each square inch, were only ground to 20-mesh.

The slight plasticity that all fine substances have, when mixed with a proper amount of water, is due to the adhesive force of the

thin film of water between the particle which, while it holds them together, also gives flexibility, and permits moulding by its acting as a lubricant between the particles; but when the water dries out there is no longer any bonding substance, and as the particles do not interlock, they fall to pieces under slight pressure. As conclusive proof that mere fineness of particles, irrespective of shape will not adequately explain plasticty, there is the very important fact that plastic clays which are repeatedly worked over day after day in clay machines at expositions become "dead" or lose their plasticity. This shows that the plasticity is not due to mere fineness, as the constant wearing and abrasive action in repeatedly passing through the machines would make the particles finer and finer; but it does show that a certain form of crystal has been worn out under this constant attrition and hence the loss of the plasticity. Again, a sample of washed clay was taken (Christy, St. Louis) which has a well developed plasticity and sieved through different sizes, and each different size was tested for plasticity by the strength test, with the following results:

Effect of Size on Plasticity.

Size of mesh.	Water Used, per cent.	Tensile Strength— Maximum.	Average.	Plasticity Ratio.
20	18.0	190	142	100
20 to 40.............	19.8	196	182	103
40 to 50	20 4	182	172	96
70 to 100.......	17.5	183	176	96
100 and smaller....	18.6	143	135	71

The results indicate that the highest plasticity was attained between 20- to 40 mesh, as it was somewhat less when coarser and very notably less when much finer. The relative amounts of these different sizes contained in a sample that had passed through a 20-mesh seive was as follows:

	Per cent.
20 to 40-mesh	24 8
40 to 50 "	21.2
50 to 70 "	1.4
70 to 100 "	12 0
100 and smaller.	39 6
Total..	100 0

This shows that the greater portion of this sample of clay was made up of the coarser and more plastic sizes, or 60.4 per cent, while the very fine sizes, or less than 100-mesh with their much feebler plasticity, made up 39.6 per cent of the total amount.

Plate Theory. The researches of Johnson and Blake were very full of facts bearing on the plasticity of clays, as their microscopic

investigation showed that clays were made up of a mixture of plates and prismatic crystals, the latter often being fan-shaped and curved. The plates varied greatly in number and fineness, and when they occurred in coarse bundles the clay was but slightly plastic, while the finer the plates, the greater the plasticity. With the finer scales was also noticed a greater amount of fine particles and the authors were inclined to credit the probable cause of plasticity to the latter rather than to thin plates. The amount of material and the extent of their observations was limited, so it is not surprising that they mistook the effect for the cause. Haworth, who investigated for this report certain samples of Missouri clays, deduced evidence that endorsed the conclusions of Johnson and Blake*, and that showed that mere fineness, *per se*, had no bearing on real plasticity, but that the condition and amount of the plates present had a very important bearing. In the non-plastic flint clays the individual particles were found to be as fine as 0.00001 to 0.000001 inch in size, but they were nearly or quite devoid of fine plates; while in the weathered plastic portion the particles were no finer, but the clay was rich in thin plates or scales, which had been separated or split apart by the frost. When the non-plastic clay was ground, which rendered it slightly plastic, an appreciable amount of scales were separated from the scale clusters, but to no such marked degree as in the much more plastic weathered sample from the same bank (Leasburg). Some of the more important examples were photographed by him, with a amplification of 60 to 950 diameters. The Deepwater shale (plate IV, figure 1) is magnified 675 diameters. This is a fair type of an average shale with well developed plasticity. From the photograph it is evident that it consists mainly of large scales or plates; a few coarse clusters are noticeable and apparently some foreign sandy matter, but the decidedly predominant structure is the large thin plate type.

In sharp contrast with the Deepwater shale was the appearance of the Munger mill kaolin, which was magnified to the very high degree of 950 diameters. Even with this high magnification the particles were found to be very small, and to mainly consist of clusters of plates, with some large, foreign, angular matter, which was presumably sand. There was a marked absence of thin plates; and this kaolin was found to be only feebly plastic.

The Moberly shale was enlarged 400 diameters. It was mainly composed of clusters of thick plates, with only a very minor portion

* Am. Jour. Sci., (2), vol. XLIII, p. 351, 1867.

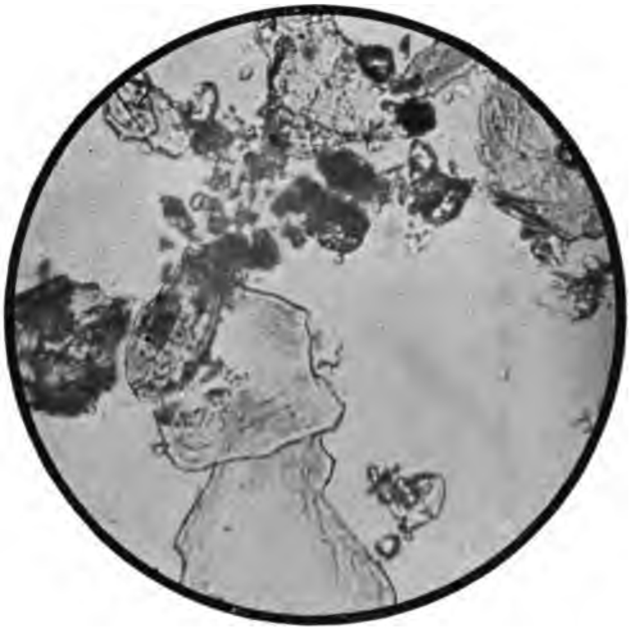


Fig. 1. MICROSCOPIC APPEARANCE OF DEEPWATER SHALE.
(PLASTIC.)

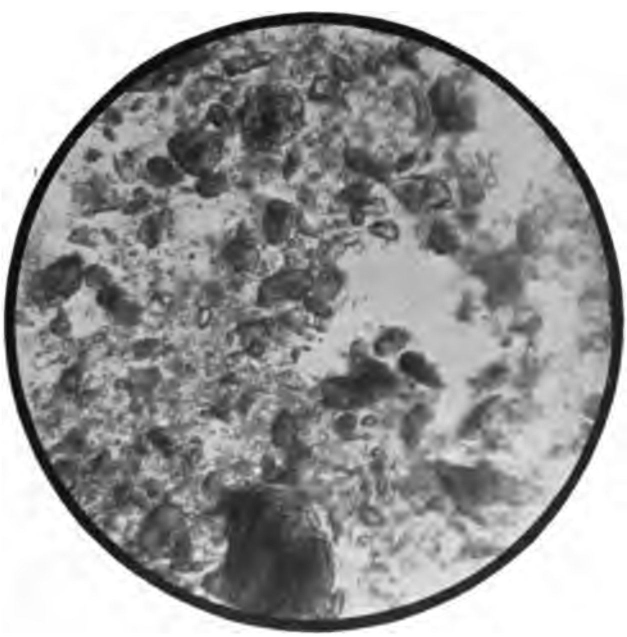


Fig. 2. MICROSCOPIC APPEARANCE OF INDIANITE.
(VERY FEEBLY PLASTIC.)

split and broken off as small thin scales. This shale is only moderately plastic, and its microscopic appearance suggests that fine grinding would greatly improve its plasticity.

The Aldrich shale was magnified 325 diameters. It contained an unusual amount of dolomite crystals, which made up one-third of its weight, while the bulk of the kaolinite was in the form of coarse, thick crystals or plates, with only a small amount in a fine state of division. This shale was only moderately plastic, or about the same as the Moberly sample.

An unweathered sample of Leasburg flint fireclay (plate V, figure 1) was magnified 950 diameters. It consisted almost entirely of fine particles or granules. These granules ranged from one-seventy-fifth to less than one-one-hundred-thousandth of an inch. There was a very striking absence of anything suggesting scales or thin plates. The clay consisted of distinct granules of various sizes though mostly very minute. This clay was found to be almost devoid of plasticity.

Weathered Leasburg flint fireclay (plate V, figure 2) was magnified 950 diameters. It was seen to differ very noticeably from the unweathered section, in that numerous coarse plates were present and occasionally apparently a few thin plates. It will be noticed that the general size of the particles is decidedly larger than in the weathered sample, yet it possesses decided plasticity, and to a very marked extent over the unweathered portion. A careful comparison of the two figures strongly negatives the idea that fineness alone is the cause of plasticity, as the very fine unweathered portion is practically nonplastic, while the much coarser weathered portion is decidedly plastic, though both samples come from the same bank of the same clay, within a few feet of each other.

The Hartwell loess clay was examined under an enlargement of 400 diameters. It seemed to contain large angular fragments, which were undoubtedly sand, and apparently some clusters of plate crystals, with only a minor portion of small plates; yet this clay was very plastic, in spite of having a very large excess of sand, which made up about one-half of its volume. If this is a fair representative of this clay, it does not have the abundance of thin plates that its very marked plasticity would lead one to expect. It does, however, lead one to seriously question whether this is really a fair sample of the clay. In the method of obtaining the samples, by differential washing, the excessive number of large fragments especially, as it was only magnified 400 times, suggests that the thinner particles were washed out before this sample was taken.

Indianite (plate IV, figure 2) was magnified only 60 diameters. When it is remembered that this was examined under such a low power, whereas the others were magnified from 325 to 950 diameters, the granules are extremely coarse. It is composed entirely of thin plates in clusters. It is needless to state that it is very feebly plastic and is usually regarded as non-plastic, though doubtless it could be rendered eminently plastic by fine grinding, as in the case of halloysite.

PLASTICITY IN OTHER LAMELLAR MINERALS.

If thin plates are the cause of plasticity, the same property should be found in other lamellar minerals, when ground so fine as to separate the individual plates by breaking up the plate clusters, and the flexibility of mica, talc, thin slates and similar minerals with a very coarse plate structure. Experiments were accordingly made which, while not as complete as desirable, show that at least several minerals with an eminent scaly structure usually regarded as absolutely lacking in plasticity can be rendered decidedly plastic upon fine grinding. The micas were not tried from the difficulty of getting them reduced to a fine state of division; and on account of their tough and greasy nature, it was found impracticable to finely pulverize either talc or pyrophylite.

Slate when ground finely, was slighly plastic, or possessed appreciable strength when dry, while when ground to an impalpable powder it possessed decided plasticity with considerable strength on drying.

Iceland spar (calcite) which has a perfect, coarse, plate-like cleavage, was moderately plastic when finely ground, and when very finely ground possessed a strength of 50 to 100 pounds to the square inch.

Prophylite, a scaly, hydrous silicate of alumina, was plastic when wet, but very tender when dry, but it was difficult to grind it very fine on account of its very greasy nature. Talc is a similar very greasy mineral, with a coarsely lamellar structure. It was plastic when wet but had no strength when dry.

Gypsum is a brittle mineral, with a coarsely lamellar structure, that can be readily pulverized to a very fine powder; it was decidedly plastic when finely ground, and when very finely pulverized was very plastic or had a strength of 250 to 350 pounds on drying.

Halloysite, a massive mineral with a conchoidal fracture, was found to have a plate structure under the microscope, but in coarse groups or clusters; it was decidedly plastic when finely ground, or had a strength of 75 to 100 pounds, and was still more plastic, or had a strength of about 150 pounds, when very finely ground.

A forcible analogy to the thin-plate theory is to be found in textile fabrics which almost owe entirely their strength to the interlocking of individual fibres. In such goods the strength is found to be largely a question of the size of the fibre, as the finer and longer the fibre, the stronger the goods, and though they attain a strength that greatly exceeds that of dried plastic clay, it is mainly due to the fact that the long fibres permit of a locking by twisting that prevents their pulling apart, whereas short fibre goods, as shoddy, have but little strength. In the pugging of clay the effort is made to reproduce this twisting action by working the clay with water, which permits of a more or less thorough interlacing of the thin plates.

The fine plate structure theory, for accounting for plasticity, is also endorsed by some other very important facts. Thus, the very plastic clays are very difficult to dry without checking or cracking, to avoid which they must be dried with great slowness; whereas other clays that are very fine as the kaolins, but only slightly plastic, can be rapidly dried without checking. This is also eminently true of the coarse-grained clays. This shows that the water added to render the clay plastic is very tightly interlocked and has great difficulty in escaping, in the very plastic clays, while it is able to rapidly escape in the slightly plastic clays. This would be the case where the water is retained between numerous very fine scales or plates, as it could move outward to the surface under capillary action with great difficulty when hampered by the interlacing of innumerable fine scales, whereas when the clay consists of sand particles the pores or interstitial spaces between the particles would make almost continuous uninterrupted short tubes for the water to flow comparatively rapidly to the surface, without warping or cracking the clay. Again, clays that require great care in drying can often be heated very rapidly without danger of checking, which shows that after the water has once escaped, the interlocking plates hold the ware with ample strength to withstand the strains of expansion, whereas the coarse plate clusters or large grains of the less plastic clay often rupture under these strains, causing checking of the ware. Thus the flint clays which are very feebly plastic, can be very rapidly dried without the least risk of checking, whereas they need the greatest care in heating and cooling to avoid checking, as there is not strength enough in the bonding of the particles to overcome the severe strains that must result from the unequal expansion (or contraction) that results because of the poor heat-conducting power of clays. The Missouri kaolins which are all lean (with one exception, Winona), can all be very rapidly dried, though very fine, yet they require very slow heating or cooling to avoid checking. The

plastic fireclays, potters' clays and shale which generally vary from plastic to very plastic, can usually be dried rather rapidly if moderately plastic, while they need more time if very plastic; they can usually be rapidly heated though there is less regularity in their action as is to be expected when there is much foreign matter, which latter greatly affects the ability to withstand rapid heating or cooling.

The fine plate theory is the only one that satisfactorily explains the reason that a given clay makes a strong resistant ware when made by the mud or plastic process, and such a weak one when made by the dry process, if only burned to a salmon brick. For in the thorough mixing of a clay with water, the lubricating action of water enables the thin plates to move over one another and to interlace when pugged or worked, which leaves the particles strongly bonded after the water dries out, and when the brick is heated these bonded scales are more closely brought together on account of the shrinkage, which results in a strong, resistant brick. But when the particles are merely pushed together in the brief single stroke of a dry press, even though the pressure be very great, there is no real bonding; and unless the clay is hard-burned it has no strength. This is best seen in the rapid way salmon pressed bricks disintegrate from frost, whereas, salmon mud bricks successfully resist the frost.

The fine plate or minute scale theory seems to most satisfactorily explain the plasticity of clays and other lamellar minerals. It clearly explains how it is that clays differ in plasticity; that some fireclays are plastic and others are not; that the clays found *in situ*, or the kaolins, are usually so slightly plastic and that the transported clays in spite of their greater amounts of diluting impurities are usually the most plastic from the weathering and abrading action to which such clays have been exposed, having split up into thin scales the scale-clusters that all primary kaolinites consist of. It explains the plasticity of weathered flint clays, and the lack of the property in the unweathered portions. It accounts for the great difficulty in drying very plastic clays; and the strength of the plastic clays both before and after burning. It clearly explains how the same clay makes such strong brick or ware when made by the mud process, and such weak ones when underburned if made by the dry process. Finally it satisfactorily explains how it is possible to over-pug plastic clays and thereby injure their plasticity, when they are persistently repugged, which is such a serious stumbling block to all the other theories but one.

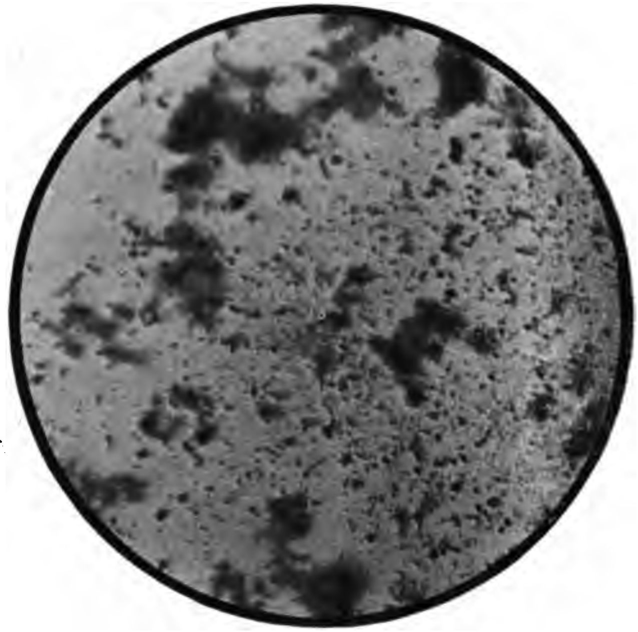


Fig. 1. MICROSCOPIC APPEARANCE OF UNWEATHERED FLINT CLAY.
(FEEBLY PLASTIC.)

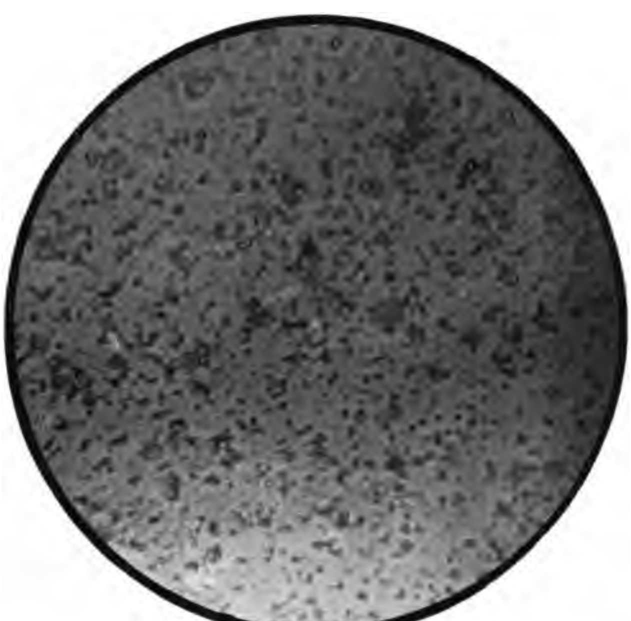


Fig. 2. MICROSCOPIC APPEARANCE OF WEATHERED FLINT CLAY.
(RATHER PLASTIC.)

DETERMINATION OF PLASTICITY.

A satisfactory method of arriving at a definite determination of the plasticity of clay is greatly desired, that this important property may be expressed in some common unit. The popular method that is used in the trade is to take a piece of clay, and work it up into a stiff paste with water; by the "feel" or readiness with which it works it is decided as to its being plastic, eminently plastic, or "lean." While this is the most satisfactory and quickest method for the experienced, to whom it gives the requisite information, it is a method that does not admit of reliable comparison, as it is a question of personality, and is very crude at best.

Bischof * suggests making up into sticks, a series of mixtures of a standard plastic clay with variable amounts of fine sand, and then rubbing them with the finger over sheets of paper and observing the amount of dust rubbed off. The clay to be compared is then similarly rubbed over other sheets of paper, and it is rated with that member of the standard series which rubs off in about equal amounts, or with equal readiness. This method is very crude, and more troublesome than the simple practical method of working it in the hand while the personal equation factor is quite as objectionable.

Bischof also suggests an indirect method of determining the plasticity that is based on the assumption that the more plastic a clay, the more water it will absorb. While, as a broad rule, it is true that the lean clays absorb smaller amounts of water than the "fat" clays, yet it by no means always follows that the greater the quantity of water absorbed, the more plastic a clay. The amount of water absorbed will be a question of fineness of grain, as the finer the grain the more water the clay takes up and retains; and while it is true that fine clays are usually very plastic, and coarse clays much less so, there are very many exceptions, as a fine scaly structure determines the plasticity and not mere fineness of grain only.

It was first thought that in testing the Missouri clays the amount of water required to produce a given stiffness of paste could be used as a measure of plasticity. But when a very lean clay (Cape Girardeau kaolin) requires 28.7 per cent and another less lean (Sterling kaolin) 35 5 per cent, while the most plastic Missouri clay found took 23.3 per cent (Norborne gumbo), and a plastic clay (Clapper potters') only required 15.3 per cent of water, it was found to have too many excep-

* Die feuerfesten Thone, p. 88.

tions of too gross a magnitude to be reliable.* In the 134 samples that were tested by this method, a fair idea was given of the relative degree of plasticity in 65 per cent of the cases, and an incorrect idea in the remainder. It was very misleading with the kaolins, gumbo (ballast) and loess (brick) clays (in 80 to 100 per cent of the cases) and less frequently so in the case of the shales (25 per cent) and non-plastic fireclays (10 per cent).

Bischof also suggests determining the plasticity by the length of the thread or cylinder that can be forced, without breaking, through a die by a hand press. At first it would seem that this would be an excellent direct method of arriving at the plasticity, and under proper precautions it would undoubtedly give satisfactory results, if sufficient time be taken to try different percentages of water, in order to arrive at the maximum degree of plasticity of each individual clay. But as the amount of water required to develop the maximum plasticity ranges from 15 to 35 per cent it would necessitate making up several batches of paste with different amounts of water, in order to arrive at the most plastic condition of a given clay, while the clay and water would have to be very thoroughly and uniformly mixed. This would involve considerable time and labor, and unless much trouble were taken the results would be liable to be very misleading.

A more satisfactory method was suggested in "Keramik" (No. 11 1869) of rolling clays out into sticks of equal dimensions, and when dried, cross-breaking them with weights after they had been supported at each end. This assumes that the dry strength of a clay will be an index to its plasticity when wet, and if the theory that the plasticity of a clay is due to the interlocking and interlaminating of plates and bundles of prisms, this should hold true. The method is crude and inconvenient, but it seems to be based on the correct principle. It therefore appeared that if the clays were made up into briquettes in the same manner as when cement is tested and the blocks broken on a testing machine that it would give an excellent relative expression of the plasticity of clays in the number of pounds required to break a square inch. It was found after thorough trial to give very satisfactory and reliable results, though there are few minor exceptions, while the amount of labor involved is not excessive. By this method it is immaterial as to the amount of water used in making the paste, provided it is plastic enough to be moulded, as the test is made on the dry clay, and any variation in plasticity in the wet clay is compensated by the variation of the shrinkage in drying, which will be proportional

*A test with precipitated silica in a very fine state of division (less than 100-mesh) which made a very finely plastic paste, took 58.8 per cent of water, or three times as much as many of the plastic clays.

to the amount of water used; so that no matter how much water is used, the clay will shrink back to a uniform size when dry. This method of determining the plasticity of a clay gives the tensile strength of the dry clay for a square inch of cross-section, and by trial it is found that the average plastic clays when perfectly dry have a tensile breaking strength of 150 pounds to the square inch. When the clay shows a strength higher than this, it is above the average in plasticity, while lean clays will show less strength if the plasticity is proportional to the strength. It was found that the non-plastic fireclays which are almost devoid of plasticity, show from 8 to 50 pounds, and average 20 pounds to a square inch; the kaolins ranged from 12 to 201, and averaged 20 pounds; the fireclays and potters' clays ranged from 50 to 284, and averaged 150 pounds. Shales ranged from 87 to 192 pounds and averaged 120; while the gumbo or burnt ballast clays ranged from 275 to 410, and averaged 340 pounds, thus exceeding many of the natural cements in strength. The loess or red brick clays ranged from 97 to 354 pounds averaging 150, but on account of being a mixture of exceptionally fine with coarse grains, they show a rather higher strength than is proportional to their plasticity, when the latter is judged from the feel, and a somewhat higher unit, about 200 pounds, is required in their case to make a fair comparison with the other clays, for which latter 150 pounds would represent a fairly plastic, easy-working clay. Hence clays and shales which show a strength of 50 pounds or less, are very lean, while lean clays range from 50 to 100 pounds; plastic clays range from 100 to 200 pounds, anything over 200 pounds possessing very great or very unusual plasticity. In the case of loess clays these limits should all be increased about 35.0 per cent.

DETAILS OF MAKING TENSILE STRENGTH TESTS.

The details for using the tensile strength method for determining the plasticity is to first work the ground clay (all clays were ground to pass through a 20-mesh sieve) with sufficient water to make a plastic mass. This is then moulded into briquettes (figure 4) similar to to those used in testing cement. There were used a set of brass moulds, having 20 to a frame, that rested on a glass plate, which were first carefully cleaned, and then oiled, to prevent the clay from adhering. The clay is added little at a time, and firmly pressed out with the thumb to fill the mould or beaten solidly into the mould with a small stamping stick, until flush with the top, when a few gentle blows with the ball of the hand completes the filling of the mould. Care should be taken in filling to add only a little at a time, as other-

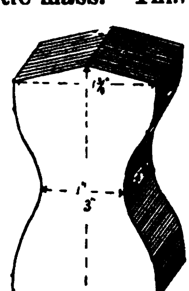


Figure 4. Briquette for Plasticity Test.

wise all the air does not escape, which makes flaws and blisters, while the same pressure or blows should be used in all cases, so as to get in the same amount of clay in each case, as the more clay or the harder it is tamped, the stronger it will be. When the moulds are filled, each of the briquettes is marked with a sharp stick with a number or letter, and then allowed to stand 12 to 30 hours, by which time it will have dried sufficiently as to have shrunk away from the moulds, and will be firm enough to be removed without injury. The briquettes are then trimmed smooth and true with a spatula or knife, and set aside to dry completely, being covered with a sheet of paper if it is a very strong clay, (to prevent cracking, by retarding the evaporation), or in the open air, if coarse. Most clays, especially if coarse, will be perfectly dry in from 2 to 5 days after removal from the moulds, or they can be hurried over a steam bath if necessary, though this is undesirable; but some very fine clays never part with all the water on mere exposure to the air, and need the aid of a steam or water bath to drive off the last of the moisture, which if present, weakens the clay more or less. When perfectly dry the briquettes are broken in a testing machine, preferably of the convenient, inexpensive type that is so largely used for testing cement, which is especially adapted for this work. Care should be taken, as with cement, to see that the jaws give a true pull in line with the axis of the briquette, and that no shearing, side, or torsional strains are introduced; while to prevent the steel jaws from biting into the soft clay, they were lined with pads of paste-board, which also takes up the play due to variations in size from the variable shrinkage. When broken, the cross-section of the area is measured and the strength figured out in pounds for each square inch. Though the moulds are made to give a section one inch square at the neck of the briquette, the shrinkage that all clays experience in drying causes a reduction of 5.0 to 15.0 per cent which necessitates the measurement of every briquette. This is quickly done with a triangular boxwood scale to one-fiftieth of an inch. On account of the difficulty of getting a uniform paste, in mixing the clay with water, in thoroughly expelling all the air in moulding, and in getting variable amounts of clay into the moulds by using greater or less pressure, as well as from accidents in drying, trimming and breaking, it is well to make at least six and preferably ten briquettes of the clay to be tested, in order to get a fair average value. Until one has had considerable experience, the clays will be found to vary 25.0 to 50.0 per cent in strength, from one or more of the above errors, but the defects usually show in the fracture. With practice uniform results can be obtained and the variation can be kept within 20.0 per cent on the same

clay. In the results given of the Missouri clays, both the average of the number of samples quoted, and the highest value of the set is given; for while the latter is the more reliable criterion of the plasticity, the average value, if not too much below it, is a good index of the character of the work, and being based on a larger number of samples, it might be preferred by some as the unit of comparison.

As the least plastic clay of 135 Missouri samples had a tensile strength of 8 pounds (average), and the most plastic clay 380 pounds, this gave a range and delicacy that is needlessly refined for practice, and hence the errors from careless or inexperienced work, which might amount to from 25.0 to 50.0 per cent, will not militate against this method for the use of the clayworker. For scientific purposes it is preferable that the moulding be done by the same operator, who should have a delicacy of touch and an equable temperment that will enable him to always use a uniform pressure in moulding, if errors are to be kept below 10.0 per cent, and the results are to be concordant. Such an experienced person will mould by hand better than by a machine, as the latter will seriously affect the results according to the stiffness of the clay. It is also safer to put half of the seemingly dry briquettes in a steam bath for about three hours, before breaking them, which will not affect the results if the clay is coarse, while it will expel the moisture that is so difficult to get rid of in the very fine clays, and which more or less weakens the briquettes. This is the method that was employed in arriving at the strength and relative plasticity of the Missouri samples, and it was found to be simple, convenient, inexpensive, and on the whole, very satisfactory; and from the wide range of the clays tested, which included every variety of clay it can be warmly recommended, where definite comparative values of the plasticity of clays is desired. Its main value is for the scientific student, rather than the practical clay-worker, as the latter can usually obtain this information by the time-honored though crude "feel" test, with sufficient closeness for most trade purposes.

CHAPTER VI.

SHRINKAGE OF CLAYS.

All clays in passing from a wet paste to a dry solid contract, the process of which is known as the air-shrinkage. They also suffer a second contraction when heated above a red heat, that is known as the fire-shrinkage. In the Missouri clays the air-shrinkage was found to range from 2.5 to 10.0 per cent; while the fire-shrinkage, when carried to vitrification, showed a greater variation, or from 1.0 to 15.0 per cent.

AIR-SHRINKAGE.

The air-shrinkage is due to the loss by evaporation of the water which renders the clay plastic. This water partly fills up the vacant spaces between the particles of clay, and partly occurs as an intervening film between adjacent grains or scales that would otherwise be in contact; the loss of the former portion entails no loss in volume on drying out, while it is the latter which gives plasticity to the clay and occasions the shrinkage on drying out. This is evident from not only a theoretical study, but from the fact that while the air-shrinkage only amounts to from 2.5 to 10.8 per cent it needs 14.0 to 35.0 per cent of water to render a clay plastic, that is, to fill the interstitial spaces and lubricate between the grains; and the difference between the water required to make a plastic paste and the air-shrinkage is the measure of the volume of these interstitial spaces. Coarse-grained clays have water mainly in the interstitial spaces, and hence suffer little contraction on drying; while the plastic clays, especially if of very scaly structure, have considerable water between the parallel scales, and such clays show a decided contraction on drying.

The coarse-grained clays, with large spaces between the particles consist of a series of comparatively large though irregular capillary tubes, and in drying these tubes are able to rapidly convey the water from the interior to the surface where it evaporates, so that the mass dries quickly and as a whole contracts uniformly without cracking or checking. When the grains are finer the number of interstitial spaces is very much increased, with a consequent increase in the water-absorbing capacity, but the tubes are much smaller, so that unless such clays are dried slowly, the exterior contracts faster than the interior, and the tubes are not able to deliver the water to the surface as fast as evaporated. Hence such clays dry slowly and check more or less. When the clay has a very fine scaly structure there is a large amount

of water between the scales; and in consequence of the strong adhesion of the water and the much more obstructed and smaller size of the capillary tubes, such clays can only part slowly with their interior water, and hence check badly if dried rapidly. If there is an inequality in the rate of drying between the interior and exterior of the clay the outer part in shrinking faster necessarily pulls apart, opens, or cracks, from the less rapidly shrinking interior; and the greater the difference in the rate of loss between the outer and inner portions, the more numerous and deeper are the cracks. Hence the coarser and "leaner" a clay, the more rapidly it can be dried without danger of cracking, while the finer a clay, the slower it should be dried; and if very plastic, especially if combined with fineness, it must usually be dried with great care and slowness, to prevent checking and cracking.

As the amount of shrinkage and freedom from cracking is a question of the size and character of grain it is immaterial as to constitution of a clay, if these two factors are not affected; hence the question of purity does not affect the air-shrinkage, except that the fine scaly structure which gives the plasticity to clay is usually more eminently developed in the impure clays. It is further found that the air-shrinkage is proportional to the amount of water used; that is, the more water used in making a plastic mass, the greater the shrinkage is for a given clay. Hence, in determining the air-shrinkage of a clay it is necessary to make it into a paste of standard or uniform stiffness or plasticity to obtain a uniform shrinkage.

The Missouri clays have the following air-shrinkages: The "flint" or non-plastic fireclays, when ground to 20-mesh consist of coarse granules, and the shrinkage averages 3.5 per cent, ranging from 2.5 to 5.0 per cent; they require about 16.0 per cent of water to make a paste which is very lean, but they dry very rapidly without the least danger of cracking. The kaolins and china clays, which are all fine grained but not very plastic, average about 5.0 per cent, ranging from 2.4 to 9.4; they require from 18.0 to 35.0 per cent of water (usually 25.0 per cent) to make a plastic paste, but as the scaly structure is generally only slightly developed they dry rapidly without cracking. The potters' clays and plastic fireclays vary from very coarse to very fine in grain, and from granular to scaly in structure, hence the shrinkage and tendency to crack vary greatly. Most of them dry rapidly, and the shrinkage averages about 7.0 per cent, ranging from 3.6 to 10 8, while the water required to make a plastic paste ranges from 14.0 to 25.0 per cent and averaged about 18.0 per cent. The shales vary in a similar way though to a less extent, and the shrinkage averages 6.0 per cent, ranging from 4.0 to 8.5, while the water required to render

them plastic varies from 16.0 to 25.0 per cent and is usually about 20.0 per cent; but they dry rapidly, in most cases without cracking. The loess or brick clays usually consist of a mixture of coarse and very fine grains, with a decided development of the scaly structure; hence they generally require slow drying, while the shrinkage ranges from 4.5 to 7.7 per cent, averaging 5.5; and they need from 16.0 to 20.0 per cent of water to render them plastic. The gumbo clays which are very fine and possess a maximum plasticity, shrink from 8.0 to 9.6 per cent in air-drying, and require from 22.0 to 23.0 per cent water.

FIRE-SHRINKAGE.

The second contraction which takes place when a clay is heated up to the point of vitrification is called fire-shrinkage. It is found to begin at a decided red heat, or at 1,200° to 1,400° F. It increases as the temperature is raised and approaches the point of incipient vitrification, and it ceases, or the clay attains its maximum density, when the clay is completely vitrified. The point at which clays begin to fire-shrink and the rate of contraction differ in different kinds. Most clays begin to slightly diminish in size at 1,400° F., though some of the very fusible or very fine-grained varieties show a slight shrinkage at 1,200° F., while the loess (or brick) and a few of the fireclays show no fire-shrinkage until heated beyond 1,600° F. They all slowly contract at first, though the very fine clays show a more uniform and regular rate than the coarse-grained. Then, as they attain the temperature of incipient vitrification (when the grain can no longer be distinguished on breaking) they shrink much more rapidly from the contraction resulting from the closing up of the pores and cavities which is completed when the temperature is raised to vitrification, as the particles are then able to move sufficiently to completely accomplish this. Any further movement after this point that results from further raising the temperature is by the clay mass as a whole, in warping or wilting, as it then begins to behave in the same way a very viscous fluid, or to slowly flow. When the point of maximum shrinkage is attained, or complete vitrification, the clay not only has its maximum density, but is also found to possess its greatest hardness, or from 6.5 to 7.0 on Moh's scale of hardness (being able to easily scratch glass) and if cooled slowly to have its greatest strength.

In heating a clay the chemically combined water which amounts to 13.9 per cent in pure kaolinite is driven off at a dull red heat, or at about 1,000° F., while organic matter (saw-dust), plants and coloring material are decomposed into charcoal and volatile products, which latter escape with the steam from the kaolinite (or the expelled chemically

combined water). The popular idea is that the fire-shrinkage is due to the reduction of volume resulting from the expulsion of this chemically combined water (and organic matter if present), and by knowing the amount of the latter it can be predicted how great the fire-shrinkage will be. The driving off of the combined water undoubtedly leaves the clay in a more porous condition which increase in porosity can be occupied by the clay particles, when the temperature is raised sufficiently high for them to move and fill them, which would occur at the vitrifying point. From a study of the results of the experiments on the Missouri clays the following table was deduced, which clearly shows that this factor alone does not explain the variations and the amounts of the fire-shrinkage:

Table of Fire-Shrinkages.

KIND.	Ignition Loss.*	SiO_2	Al_2O_3	CaO	MgO	Fire-Shrinkage.	Grain.
FLINT FIRECLAY:							
Maximum (Union)..........	13.84	44.14	39.86	0.77	0.46	14.0	Very fine.
Minimum (Owensville).....	12.20	44.70	35.92	3.00	0.21	4.3	Coarse.
Average of 9	*13.4*	......	....	.....	...	*9.9*	Mostly coarse.
KAOLINS:							
Maximum (Sterling)........	11.43	57.75	27.60	0.24	0.31	15.0	Very fine.
Minimum (Thayer).......	4.62	81.18	12.14	0.16	0.14	8.3	Fine.
Average of 7	*6.3*	.....	....	......	......	*8.8*	Mostly very fine.
FIRE AND POTTERS':							
Maximum (Victoria)........	12.36	45.97	36.85	1.14	1.09	12.2	Very fine.
Minimum (Clapper)......	7.80	67.76	21.96	0.96	0.24	1.5	Very coarse.
Average of 58...........	*8.9*	......	....	......	.....	*5.4*	Mostly coarse.
LOESS CLAYS (BRICK):							
Maximum (Hannibal)	5.26	73.80	13.19	0.86	0.68	5.9	Fine and coarse.
Minimum (Hartwell)	5.30	60.93	21.51	0.52	0.88	2.2	Fine and coarse.
Average of 7	*5.0*	......	....	......	.....	*4.5*	Fine and coarse.
SHALES:							
Maximum (Lexington).....	7.54	54.03	22.50	0.85	2.70	7.4	Fine.
Minimum (Aldrich)††	18.02	46.26	10.76	11.08	7.84	1.0	Coarse.
Average of 25	*7.4*	.. ..	....	......	.....	*4.6*	Mostly coarse.
Average, above 106 clays and shales	**8.5**	.....	....	.....	.....	**5.7**	
GUMBO CLAYS:							
Maximum (Clifton).........	9.88	62.80	17.22	0.98	0.78	1.5	Very fine.
Minimum (Norborne).......	13.62	54.90	18.03	2.88	1.10	1.4	Very fine.

*Ignition loss also includes organic matter and carbonic acid (CO_2), though in most cases it represents only combined water.

†The fire-shrinkage is carried to the vitrifying point or maximum shrinkage.

††This clay expands 10 per cent when vitrified, from the large excess of lime.

In the case of the "flint" (non-plastic) fireclays which are usually remarkably pure, there is only a variation of 12.2 to 13.8 per cent in the water, yet there is a range of 4.3 to 14.0 per cent in the fire-shrinkage. The average amount of combined water is 13.4 per cent, yet the average fire-shrinkage is only 9.9 per cent, or nearly 50 per cent less than the loss due to the water. In all cases the clays were ground to pass through a 20-mesh sieve, but in the case of flint clays, the powder was mainly made up of coarse grains ranging from one-fortieth to one-twentieth of an inch in size. The kaolins, with a variation of 4.52 to 11.43 per cent of chemically combined water, show a range of 3.3 to 15.0 per cent in the fire-shrinkage, and average 8.8 per cent. As they are all fine to very fine in grain this accounts for the shrinkage exceeding, by about 40 per cent, the amount of water that is expelled. The loess clays (brick) which are a mixture of very fine and coarse grains show less variation, in both the water and fire-shrinkage, than the other clays, and the average amount of water, or 5.0 per cent, is but 10.0 per cent greater than the average amount of shrinkage, or 4.5 per cent. The fireclays and potters' clays, which vary from very fine to very coarse, vary from 1.5 to 12.2 per cent in shrinkage and average 5.4 per cent; yet they average 8.9 per cent of chemically combined water, or they shrink about 40 per cent less than the amount of water present. By studying the complete tables it will be seen that in a few cases the fire shrinkage just equals the amount of water expelled, and in still fewer cases it exceeds it; in both instances the clay was fine to very fine. The gumbo clays, which are very fine and extremely plastic, have from 9.0 to 14.0 per cent of water, yet they shrink only 1.0 to 2.0 per cent in burning. The shales which are mainly coarse-grained, also show a fire-shrinkage that is nearly 40 per cent less than the amount of water expelled, for while they average 7.4 per cent in water, the average fire shrinkage is only 4.6 per cent. Hence, while the greater amount of water to be expelled the greater is the shrinkage, the amount of shrinkage mainly depends upon the size (and character) of the grain, as the finer the grain, the greater and also the more regular is the shrinkage, and the higher the temperature usually before it begins. Of these two factors the size of grain is of much greater importance in influencing the amount of shrinkage than the amount of water to be expelled.

There are also other factors which have an influence on the amount of shrinkage, besides the expelled water, organic matter, and the size of grain. The Aldrich shale which has 11.0 per cent lime and 7.8 per cent magnesia expands 1.0 per cent when vitrified, or enlarges instead of contracts. The Owensville flint clay, with 3.0 per cent of lime,

only shrinks 4.3 per cent though it has 12.2 per cent of water and organic matter. The Mayview clay which is fine-grained has 9.9 per cent lime and 2.7 per cent magnesia, but it shrinks only 0.8 per cent, though 15.0 per cent is expelled on ignition that consists of chemically combined water, carbonic acid and organic matter. The Glenwood clay which is also fine-grained has 8.5 per cent lime and 2.2 per cent magnesia, but it shrinks only 1.5 per cent, though 12.8 per cent is expelled by ignition. In these cases the lime and magnesia strongly counteract the shrinkage, even causing expansion in the case of the Aldrich shale (which is remarkably high in the alkaline earths), but they are present as carbonates. The loess clays from Kansas City, Boonville and Jefferson City have from 3.0 to 4.0 per cent of lime and magnesia, yet they have a normal shrinkage that is consistent with their grain and combined water; while the very fine Albany slip clay, with 5.8 per cent lime and 3.3 per cent magnesia shrinks 8.0 per cent, and has 8.9 per cent combined water; but in these cases the lime is probably present as a silicate in the form of feldspar and hence it is not converted into caustic lime which swells by heating and so it has no influence on the shrinkage. Hence if lime and magnesia are present in the form of carbonates to a greater extent than 1.5 per cent they have a tendency to reduce the shrinkage, which is the more marked as they increase above this minimum amount when their influence is thus felt; if present as silicate (as feldspar or chlorite) they do not reduce the shrinkage. In the large majority of clays and shales the amount of carbonate (and sulphate) of lime and magnesia is not sufficient to have any modifying action on the fire-shrinkage.

Free silica, as sand, also affects the shrinkage but in a negative manner, as a mere diluent; for while it has no effect itself it dilutes the kaolinite base and so tends to diminish the shrinkage which is the more marked the higher the clay is in free silica. Its action is only noticeable when present in large amounts, while the fineness still remains a very important factor, as the coarser the free silica or sand the less does the clay shrink. Thus the Thayer kaolin which is fine-grained shows a fire-shrinkage of only 3.3 per cent, though it has 4.5 per cent combined water, and only 0.3 per cent lime and magnesia, but it has 81.2 per cent of total silica. The Clapper fireclay which is coarse-grained has 67.8 per cent total silica, and 1.2 per cent lime and magnesia; but it shrinks only 1.5 per cent, though it has 7.8 per cent water. The Gilkerson Ford fireclay which is fine-grained and has less than 1.3 per cent lime and magnesia shrinks 6.0 per cent though the ignition loss is only 3.9 per cent and the silica amounts to 77.0 per cent. Hence, a clay that is fine-grained and high in free silica may shrink

more than a coarse clay that is purer and lower in sand; but the general tendency is that in clays of similar fineness the fire-shrinage decreases as the silica increases, by the latter displacing and diluting the kaolinite or shrinking base.

The most potent factor in influencing the amount of fire-shrinkage is the size of grain; the finer it is the greater the shrinkage. The fire-shrinkage usually ranges from 50.0 per cent less than the loss due to ignition in the coarse clays to 40.0 per cent greater in the very fine clays. The amounts of chemically combined water and other matter that is expelled on ignition are very important factors and the greater this loss the greater the shrinkage, other things being equal. The amount of sand or free silica present is a less important factor in diminishing the amount of shrinkage, but other things being equal, the more sand the less the shrinkage though the coarseness of the sand is much more important than the amount, as the coarser the sand, the less the shrinkage. The amount of lime and magnesia present as carbonate is very important in reducing the shrinkage, which influence is felt when they exceed 2.0 per cent and increases until they exceed 15.0 per cent, when the shrinkage is eliminated. As they are usually present as silicate, which has no noticeable influence on shrinkage, they do not often have to be considered, as it is exceptional to have them present in the form of carbonates.

TIME FACTOR IN FIRE-SHRINKAGE.

There is a popular idea that the longer a clay is exposed to a given heat the more it shrinks, though the temperature be constant. Were this true it would be only a question of time when clay would shrink to nothing. Still there is a foundation for this idea, for in burning most ware as soon as the temperature is attained that experience has shown to give satisfactory results the fires are allowed to burn down and the kiln is either shut up tight, or is allowed at once to rapidly cool off. Under such conditions a certain fire-shrinkage is found to take place. Now, if the fire is maintained for sometime at the highest temperature before closing up the kiln or cooling it off, a greater shrinkage is found to take place in burning thick or heavy ware, which is due to the simple fact that unless this highest temperature is maintained for sometime the heat has not sufficient time to penetrate to the center of the ware, on account of the very poor and very slow heat-conducting power of clay. Hence unless enough time is taken to enable the maximum temperature attained to penetrate to the center of the thickest articles, the shrinkage will be a compromise between the hotter exterior and

cooler interior of the ware, and therefore is not as great as if the entire body had reached the maximum temperature.

The speed at which the heat is conveyed to the interior of a given clay in burning depends on the grain of the clay, as the coarser the grain, the slower the heat is conveyed; on the thickness of the ware, as the greater the thickness the longer the time required to reach the center; and on the temperature, as the higher the heat, the more rapidly it penetrates into the interior. Hence all clay-ware of equal thickness does not heat up with equal speed, as in addition to the above physical causes of variation, the purity of a clay has a decided influence in most cases, as the less pure, the more rapidly it is likely to convey heat, if the impurities are very fusible or very dense; while the specific gravity or density also has a decided influence in affecting the conductivity of heat, which is the greater the denser the clay.

In testing the Missouri clays for fire-shrinkage, the tests were made on two sizes of bricklets that were one-half by one by four and one by one by four inches respectfully. It was found that the one-half inch thick samples required from one-half to one hour to heat completely through, and that the one-inch thick samples require from 1 to 2 hours; after that time there was no further increase in the shrinkage. Special tests were made to cover this point, in which samples of each size were taken out with a differential in the exposure of 1 to 2 hours, beginning after 1 hour's exposure, and extending to 36 hours; in no case was the shrinkage found to be any greater after a prolonged exposure, where the temperature was constant, when sufficient time (one-half to two hours) had elapsed for the samples to be heated throughout to the maximum temperature.

METHOD OF DETERMINING THE SHRINKAGE.

The method used in determining the shrinkage in the Missouri clays and shales was to grind all the samples to the uniform fineness of 20-mesh, which was accomplished in a sampling mill (coffee mill pattern) through which the air-dry clay sample in lots of 40 to 50 pounds was passed until it would all go through a sieve with 20 holes to the linear inch. The ground clay was then mixed with distilled water in the case of the high grade clays (fireclays, potters' clays, china clays and kaolins) or with clear river (Mississippi) water in the case of the brick and paving clays, until brought to the consistency of a stiff, plastic, easy-moulding paste. Ten to 20 pounds of the dry clay were taken (usually the latter) and the amount of water used was carefully measured to the nearest ounce. The clay and water were mixed to a uniform dough or paste by hand, after the manner of making bread, and

water was added, little at a time, until a proper consistency was reached. Great care was taken to obtain a uniform consistency of the mud as near as one is able to judge by the feel. The relative degree of plasticity and the amount of water thus used are the quantities given in the table, and this rating was as carefully made as such an eminently personal matter can be when the work extended through three years and much of it carried on jointly by two persons.

The paste was moulded by hand into four sizes of bricklets $\frac{1}{2} \times 1 \times 4$, $1 \times 1 \times 4$, $2 \times 2 \times 4$, and $3 \times 4 \times 8$ inches respectively, which cover about all the sizes of ware that are usually made in the plastic arts, excepting furnace blocks (which are thicker) and high grade china (which is often much thinner). The moulding was done by throwing and working a ball of clay on a block of wood by hand into one of the above sizes, and afterwards trimming to sharp edges and smooth faces with a steel spatula; by exercising sufficient care the leanest of clays could be successfully patted out into these bricklets, while the rounded edges and untrue surfaces were easily and quickly removed by the careful use of the sharp spatula. One complete set of the above sizes was made for trying rapid drying, and another complete set for slow or air-drying, while about six each of the one half and one-inch thick sizes were made for testing the fire-shrinkage. As soon as moulded, a fine line was drawn along the middle of the bricklets with a straight-edge and spatula and its ends defined by cross lines (figure 5).

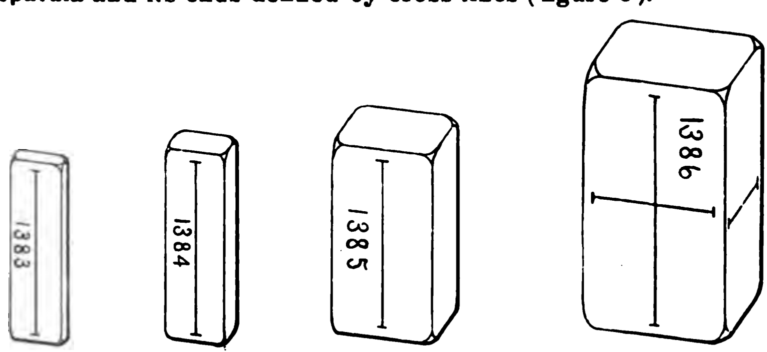


Figure 5. Suite of Bricklets for Determining Shrinkage.

The length of the freshly moulded wet bricklet was at once measured to within one-one-hundredth of an inch and each bricklet was given an individual number that was scratched in the soft clay with a pencil. A set of the different sizes of the bricklets, such as is shown, was at once put over a stream or air-bath, where it was subjected to a heat of 200° to 212° F. to test the ability of the clay to withstand rapid drying. The rest of the bricklets were allowed to air-dry, the samples being placed on boards covered with a thin layer of sand, to

prevent them from sticking and to assist the drying out of the water. The bricklets were watched during the drying to observe any warping or cracking and before they were entirely dry they were scraped free from adhering sand. When dry as judged by feel and color they were all remeasured. The difference between this measurement and the previous one as a wet paste gave the air-shrinkage, or the contraction due to the loss of water that rendered the clay plastic. It was found that after once drying the bricklets did not vary in dimensions whether exposed to a very damp atmosphere or a very dry warm one, though a nominally dry clay always retains from 0.5 to 4.0 per cent of moisture (usually about 2.0 per cent). The number of specimens tested for air-shrinkage ranged from 10 to 20, usually 16, and the average was taken, which, as previously mentioned, was found to range from 2.5 to 10.8 per cent, while the amount of water necessary to make a stiff, plastic paste ranged from 14.0 to 35.0 per cent, usually about 18.0 to 20.0 per cent.

The fire-shrinkage was obtained by burning two or more of the $\frac{1}{2} \times 1 \times 4$ sizes to the point of vitrification and holding them at this heat for several hours and remeasuring. The difference between the vitrified sample and the air-dried measurement gives the fire-shrinkage, which is divided by the original wet length to give it in percentages of the original or moulded length. From one to six specimens of each were carried to the point of complete vitrification (usually three) and the average taken. If heated to less than this temperature, a smaller shrinkage was of course always found, but these were ignored in making up the figures given for the fire-shrinkage given in the tables, which represent the maximum fire-shrinkage.

VARIATION IN SHRINKAGE.

The air-shrinkage is found to vary in a given clay not only for different amounts of water, but also in samples made from a given paste where the percentages of water are supposed to be the same. This variation is sometimes considerable, exceeding 50.0 per cent in extreme cases, yet no reason for the cause is evident from external appearances. Upon breaking the samples they often show more or less porosity and even large air spaces, from failure to expel the air in working the clay. Another serious cause for variation in the air-shrinkage is from the lack of uniform mixing of the water and clay in the paste, so that some portions of the paste contain more water than others, with a consequent variation in the amount of shrinkage. Again, a clay shrinks less the more thoroughly it is worked which not only insures the exclusion of air and uniformity in the water but also results in greater density and

more complete filling of the interstitial spaces with the very fine clay particles, and hence with a consequent diminution in the contraction. Finally, any variation in the pressure or force used in moulding the clay whether done by hand or machine results in a variation in the density, with a consequent variation in the shrinkage. While thorough, careful, uniform working of the paste eliminates these variations and results in a paste that gives a uniform shrinkage, this in practice is at best but imperfectly done. The air-shrinkage is therefore averaged from a large number of samples so as to eliminate these variations as far as possible. It was found to require very great care in making the bricklets to keep the variation within 10.0 per cent. This is one of the great advantages that the dry-press method of moulding has over the stiff- or soft-mud methods; the variations in the size of the dry-moulded ware are entirely eliminated and the ware is subject to less fluctuations in the fire-shrinkage.

The stiff-mud method of moulding has the advantage over the more plastic wet-mud method (where more water is used) in that there is less water to evaporate and hence less shrinkage, though there is greater difficulty of eliminating the air and getting a uniform mixture when the mud is stiff; but the very much greater pressure under which stiff mud machines operate produces an article that is more dense and solid than by the soft-mud process. The product not only shrinks much less but also varies less in the shrinkage than by the latter process, which is operated under only a moderate pressure.

The variation in fire-shrinkage is due partly to the presence of air and lack of uniformity in the working of the clay or the pressure in moulding, as in the air-shrinkage, but mainly to differences in the temperature at which the clay is burned. If samples of clay are exposed to different temperatures (and it needs a highly trained eye to make even a rough discrimination at high temperatures) there is necessarily a difference in the shrinkage which is greater the higher the heat (until thoroughly vitrified) while the rate of shrinkage is greater just before vitrification than in the beginning at a red heat. Again, when samples of the same clay, but of variable thickness, are exposed to the same temperature, there is a variation in the amount of shrinkage if sufficient time is not given for the heat to penetrate to the center, and thus become uniform throughout. This needs considerable time on account of the poor conductivity of clay. The lack of time and lack of uniformity in the temperature are the main causes for variation in the fire-shrinkage; and in making the tests on the Missouri clays it was found very difficult to keep this variation within 10.0 per cent.

ERRORS OF THE WEDGEWOOD PYROMETER.

The Wedgewood pyrometer which attempts to estimate high temperatures by the amount of contraction in a cylinder of dry clay, which has been exposed to the heat that it is desired to measure, is therefore a very unreliable instrument. For it is a difficult matter to obtain cylinders of a uniform homogeneous composition that have been moulded under equal pressure. Unless such perfect homogeneity is obtained the shrinkage is erratic and variable for the same temperature, because of such lack of homogeneity; while the amount of shrinkage is not proportional to regular increments of temperature, as the clays shrink more rapidly when raised to a very high heat, or as they approach the vitrifying point, than at a lower heat (as a bright red) when the particles seem less able to move among themselves. Again, if sufficient time is not given for the cylinder to obtain uniform temperature, the shrinkage is not as great as it should be for the given heat, by the center not being able to shrink as much as the hotter exterior. Even when a given clay has had the shrinkage determined for given temperatures (and the finer the clay the more regular and better it works) the variations in temperature in different parts of the clay cylinder on account of its poor conductivity together with the above working variables in making the cylinders, would make it extremely crude, and liable to errors of 10.0 to 40.0 per cent.

PRACTICAL IMPORTANCE OF SHRINKAGE.

The practical bearing of shrinkage is very important in using a given clay, in order to know how much larger it is necessary to mould an article so that after burning it will shrink to a given size. For all clay ware that is made to specific dimensions the amount of shrinkage has to be carefully determined, and for special purposes, as in furnace blocks which have to be made an exact size, there is an expense for dressing and trimming if a uniform size is not secured. As the shrinkage differs in different clays, ranging from 5.0 to 25.0 per cent, every clay must be tested by itself under exactly the same conditions through which it passes in the operations by which it is worked. It should be ground to the fineness used in practice; then uniformly mixed with the water requisite to give it the plasticity that is desired; then moulded under the same pressure that is used in practice; and finally dried to determine the air-shrinkage. Then it should be fired to the temperature that gives it the hardness or body that is desired, and kept at this heat long enough for it to "soak" or penetrate to the center, when the fire-shrinkage is obtained. The sum of the air- and fire-shrinkages or the

total shrinkage is the increase in size that moulds, dies, templates or patterns have to be made in order to have the finished, burned goods of the proper dimensions. The less a clay shrinks, the more valuable it is, other things being equal, as the less is the allowance to be made in the "shrink scale," and the less the risk and possible variation in size from imperfect or careless working, while the freedom of the clay from cracking and checking greatly diminishes as the shrinkage decreases and the more rapidly it can usually be dried and burned.

Since clays with low shrinkage are exceptional, as the range is usually from 10.0 to 12.0 per cent when moulded from a stiff mud or paste, it is often necessary to reduce such a large and more or less variable reduction in volume, with a marked decrease in the risk of cracking, by the use of dilutents that do not injure or affect the ware; by thus replacing the shrinking clay they reduce the shrinkage by the amount to which they are used, and enable the ware to be dried and burned more rapidly. The dilutents or "shrink-reducers" that are used for this purpose are sand or crushed quartz, burnt clay, crushed brick and pottery, or "pitchers" which, under the techinal name of "grog," are used as freely as the clay permits, without rendering it too lean, or interfering too much with its plasticity. Sand and ground quartz or flint act merely by displacing so much clay, and only reduce the shrinkage; but burnt clay or old fire brick or other non-vitrified ware not only act equally as well as body dilutents, but their porous character also aids in hastening the drying, by assisting the escape of the water from the center (both in air-drying and burning) and are therefore very much more valuable in preventing cracking and checking.

The amount of "grog" necessary for a given clay depends primarily on the peculiarities of the clay itself, the amount of shrinkage and the thickness of the article. There is an individuality about every clay that makes all general rules more or less unreliable, but as a broad statement, the grog should be increased the greater the shrinkage, and the thicker the article or price to be made. For the thicker the piece the greater is the difference between the out- and inside dimensions or measurements, as the ware dries from a stiff mud, or is heated in the kiln, and hence the greater the risk of cracking and the larger the cracks. When the shrinkage is moderate, and hence the clay is rather lean, as little as 10.0 to 15.0 per cent of grog will often overcome all risk of checking or cracking in either drying or burning. If the clay is finer and more plastic, 25.0 to 35.0 per cent may be necessary; while if the article is very thick, it may need 50.0 per cent of foreign material.

It is seldom that a clay is so "strong" or very plastic that more than 50.0 per cent grog is needed, as such a large amount as this tends to render it too lean and not strong enough even after burning, while the grog is very severe on the moulds and dies in quickly cutting them out. In the case of very large, heavy furnace blocks, which are occasionally over two feet thick, as high as 65.0 per cent of grog is occasionally used, though this is very exceptional.

OHAPTER VII.

FUSIBILITY OF CLAYS.

The fusibility, or the temperature at which a clay fuses, is a very important question in every application of clay in the plastic arts. Even in making brick and terra cotta it is very essential to know this point; for while sufficient heat is necessary to give the requisite strength and hardness to carry the load and to resist the weather the ware should not be vitrified or semi-fused, as this renders it more or less brittle, and the increased density resulting therefrom injures the excellent non-conductivity of heat, which makes it so desirable as a building material. For paving brick and sewer pipe, on the contrary, the clay should be just vitrified or barely fused, to give strength, hardness and non-porosity that is desired in this class of goods. In potters' clay it depends on the specific application of the clay as to the urgency of this information. Earthenware and majolica are not vitrified and their porous body is made non-absorbent by the use of glazes; while chinaware is vitrified to render it translucent, dense, non-porous and strong. In fireclays or refractory clays the vital question is the ability to resist heat. While pure kaolinite is infusible at the highest temperatures attainable in ordinary wind furnaces, most refractory clays are more or less affected and many so-called fireclays are too fusible to be used at even moderate furnace heats.

DEFINITION OF FUSIBILITY.

As there is a very indefinite, undetermined limit as to when a clay ceases to be refractory, and a still less appreciation of the manner in which a clay fuses, it will be necessary to define these points before discussing the fusibility of fireclays. The term fusibility in the sense in which it is properly used, as when a metal liquifies, is very misleading when applied to clays, as it conveys the idea that the solid clay or fire-brick suddenly becomes fluid; whereas clay as its temperature is raised, very gradually passes from the condition of a solid to a very viscous fluid and if heated high enough it may finally become a mobile fluid like a slag of molten metal. Long before this latter condition is

reached the clay or brick would fail by its swelling, distorting or sagging, and hence would be worthless to maintain a furnace wall or arched roof, or carry a load, or withstand abrasion. On heating a clay beyond red heat it is found to become harder, to shrink, and to become close-grained as the temperature is increased. On heating it still farther a point is reached when it becomes very hard, attaining a hardness of 6.0 to 6.5 (easily scratching glass); it has almost completed shrinking, it has become very strong, and the individual grains can no longer be recognized. This point is called the point of incipient vitrification. While the clay lacks all signs of fusion and is stiff and rigid at this temperature it shows sufficient flow or movement of the particles towards one another to obliterate individual grains and thereby attains greater density, as it has a decided resemblance to being vitrified. On heating the clay from 100° to 300° F. above this point of incipient vitrification the density is still further increased, by a further and final shrinkage; the hardness becomes somewhat greater, or from 6.5 to 7.0 (now scratching quartz), while the grains are not only completely obliterated but the fracture is now like that of china or vitrified ware. This point is called the point of complete vitrification and the clay still stiff retains its form and shape, though it shows greater movement among its particles. On heating the clay from 100° to 400° F. still higher the clay begins to warp and sag, slightly at first but more readily as the heat is increased, and to swell or blister; while on breaking it it is found to be more or less vesicular and scoriaceous. This point is called the point of viscous or scoriacious vitrification, as the particles are now sufficiently fluid that chemical re-actions begin which give rise to the gas bubbles that cause the clay to swell and give it the vesicular structure; and although it is too stiff and pasty to become decidedly liquid, it has attained a temperature when it would fail in all the practical applications of the clay.

If the temperature is raised still higher the material becomes more liquid, until finally it is thin enough for the gases set free by the chemical reactions to escape, and it then resembles so much slag. It is now said to be completely fused and on cooling it gives a dense, compact stony or vitreous fracture; but the clay would have become worthless long before this stage of liquidity is reached, so that the idea of fusibility in this sense has no value to the clay-worker. The three terms "incipient", "complete" and "scoriacious" vitrification have been introduced and are used throughout this report to indicate the temperature to which a clay should be raised to develop its strength and hardness in the first case; to bring out its maximum density, strength, hardness,

and render it non-absorbent in the second case; and fix the failing point of the clay to withstand pressure, abrasion or distortion, in the third case.

RANGE IN VITRIFYING POINTS.

In attempting to define the three stages in the transition of a solid clay to a very viscous fluid the lines cannot be sharply drawn, and except the last stage can only be appreciated when the clay is cold and has been fractured. It was found that from the point when the grain of the raw clay was lost, and it attained a hardness of 6.0 to 6.5, or the point of incipient vitrification, to the point when it gave a vitreous fracture, was non-porous and had a hardness of 7.0, or was completely vitrified, required an increase of 150° to 300° F. In the very impure shales and clays 150° F. was usually sufficient, while in the better grades 200° F. was the general rule, though a few of the very fine-grained china clays needed 300° F. From the point of complete vitrification to the point of viscous or scoriaceous vitrification it was found to require an increase of 100° to 400° F. In the very impure loess clays and in the shales or clays with much ferrous oxide 100° was usually sufficient; but most shales and clays needed 150° to 200° F., and the very pure fireclays and a few very fine-grained china clays required 250° to 400° F.

Of the 135 samples of clays and shales tested it was found that the range between the point of incipient vitrification, or when a clay has attained great strength, density and hardness, to which point most clay ware is burned, and the point of scoriaceous vitrification, or when a clay fails, was as follows:

Number.	Percentage.	Range.	Character.
2	1.5	75° F.	Very calcareous.
33	24.5	300° F.	Very impure clays and shales.
11	8.0	350° F.	Less impure clays and shales.
63	47.0	400° F.	Fireclays, potters' clay, kaolins.
26	19.0	500° F	Some china clays, pure fireclays.
135	100.0	400° F.	Average.

The range between the lower limit, to which point most clay wares have to be brought to give them strength and hardness and the failing limit to which point no clay wares should be exposed is the margin permissible in burning a kiln to get satisfactory results, if vitrification is not objectionable; and this averages 400°F., as shown in the table. The two samples of very calcareous (as carbonate) shales in the table,

which are really shaly marls, show the very low range of only 75° F., and it would be impossible to burn them to a hard strong ware, as kilns cannot be regulated within such a narrow margin, so that the ware made from such marls would be too soft, from underburning, or wilted and ruined from overburning.

WHAT IS A REFRACTORY CLAY?

The popular idea of a refractory, or fireclay, is one that can successfully withstand a high temperature, but just what is meant by a high temperature is very indefinite. Very erroneous and extremely variable ideas exist among fire-brick manufacturers as to the temperature at which their kilns are burned, and the clays are able to withstand. The users of fire-brick usually have a better idea of the temperature to which the brick is exposed, but according to their speciality, their ideas vary greatly as to what is a high heat. The high heat of a lead smelter is a very much lower temperature than the high heat of a steel-smelter. As reliable and convenient pyrometers have been at the command of scientists for only a short time and have not yet been introduced into commercial practice to any extent, this lack of harmony in the ideas of furnace operators, and their greater or less ignorance of the temperatures they are actually using, is excusable to some extent, as especially many of the books still contain the old and very erroneous determinations made with the earlier crude pyrometers.

There is such a marked difference in the conditions to which fire-brick are exposed as to make a fireclay that is successful in one place quite valueless in another. There is the very great range of being exposed to only 800° to 1,500° F. in flue-lining and bake-ovens; to 1,800° to 2,400° F. in lead, zinc, and copper smelting; and from 2,400° to 3,000° F. in glass pots, iron furnaces and steel works. The intelligent maker of refractory material meets these variable conditions in temperature, corrosive or slagging action, and mechanical or abrasive action, by having several mixtures of clays and burned material with which to make different grades of brick to meet the variable requirements in fusibility, corrosion and abrasion. A clay that melts in the heat of a steel furnace may be most satisfactory in many other metallurgical operations that do not use such high temperatures, and even more durable from its greater toughness and ability to withstand changes of temperature than a more refractory clay. As the term "fireclay" is therefore largely relative, being applied to those clays which successfully withstand moderate furnace heats, as well as to the few very refractory clays which are not affected by the highest tem-

peratures it is usually qualified by the terms moderately refractory, refractory and very refractory.

As the great majority of furnace operations are carried on at a lower temperature than 2,500° F., as in brick and pottery kilns, gas works, gas producers, coke ovens, roasting furnaces, lead, copper, and zinc furnaces, flue and chimney linings, assay furnaces, boiler furnaces, calciners and bake-ovens, this figure has been taken as the dividing line between those clays that are entitled to be called refractory or fireclays, and those that are not entitled to that distinction. If a clay can be heated to this temperature before it fails or reaches its viscous or scoriaceous vitrification point it meets the demands of most of the applications of fireclay. For glass pots, iron and steel furnaces, which are liable to reach higher temperatures than 2,500° F., a more refractory clay must be used. A clay that fails at 2,200° to 2,300° F. may still be successfully used in places where the temperature never goes above 2,000° F., but in most furnace operations the risk of reaching a temperature of 2,300° to 2,400° F., through carelessness in firing or design, requires the limit to be placed at 2,500° F., to be reasonably secure from accident. This is the temperature of a pure white heat.

FACTORS OF REFRACTORINESS.

The fusibility or refractory value of a clay depends on three factors:

(1) The amount of fluxing impurities;

(2) Density; and

(3) Fineness of grain.

The first consideration is the freedom of the clay from detrimental impurities as the alkalies, iron, lime and magnesia, that have a more or less strong fluxing action, and which render it the more fusible the larger the amount. As pure kaolinite is infusible at the highest heat obtainable in furnaces (though it can be readily fused in the intense heat of the oxy-hydrogen flame, or in the electric arc) the purer the clay, or the more nearly it approaches kaolinite in composition, the less fusible it is. But as already mentioned in the chemistry of clays, there are two classes of impurities in all clays, the non-detrimental, as silica, titanic acid, water and organic matter, which do not affect the fusibility, and the detrimental, that are also known as the fluxing impurities which affect the refractoriness of a clay. The influence of these fluxing impurities and the amounts that are permissible in fireclays are discussed elsewhere, as well as the marked difference in the form of combination in which they occur in a clay, which latter fact is

totally ignored in a chemical analysis, with the consequent uncertainty and probability of error in the interpretation of the analysis.

The influence of density has already been discussed, or the fact that the denser a clay or the higher its specific gravity, the more refractory it is, other things being equal. The value of the density factor, from a pyrometric study of the Missouri clays; shows that for every increase in density of 0.20 to 0.25, the fluxing impurities can be increased from 0.50 to 1.50 per cent without lowering the refractoriness. As clays are liable to vary from 1.50 in the superficial deposits to 2.50 in the coal measures clays and shales that have been subjected to heavy pressure the density factor is very important, though greatly underestimated and overlooked by the early investigators. The finer the grain of a clay, the more fusible it is.

As no unit has been yet determined by which to measure the relative fineness of the grain it is still premature to give definite statements as to the value of this very important factor, which has been so ignored by chemists and not fully appreciated by clay-workers, though manufacturers of refractory products are well aware that the finer clays are ground or are mixed with grog the more fusible they become. The slacking of a clay gives an excellent method of arriving at a correct idea of the relative fineness, as the particles range from one-fourth to one-twentieth of an inch in coarse clays; from one-fortieth to one-one-hundredth of an inch in fine clays, and are less than one-one-hundredth of an inch in very fine clays.

The composition and density of two clays being the same the question of fineness is liable to make a difference of 200° F., or more, in the fusibility. This is well illustrated in the Clapper fireclay in which two samples from the same seam differ by 300°F. in refractoriness, though they have practically the same density and composition; but one is from the upper portion of the bed, where it has been exposed to weathering and is in a fine, plastic condition, whereas the other is from the lower portion of the bed and is coarse-grained and non-plastic.

DETERMINATION OF REFRACTORINESS.

There are two methods of arriving at the refractoriness of a clay, one physical and the other chemical. The physical methods attempt to determine it directly by contact or association with the clay that is being tested, by the use of pyrometers, or by fusible mixtures or alloys that have previously had fusing points determined.

The chemical methods attempt to arrive at the result by calculations based on the chemical analysis, though one or more initial

pyrometric determinations have to be made as a basis for these calculations. As the former method is direct and there are now reliable and convenient pyrometers in the market, it is the only method that should be followed when it can be done with a reliable instrument in the hands of an experienced operator; but as these latter conditions are often lacking, and it is frequently desirable to know the probable refractoriness of a clay of which only the analysis is available, the chemical or indirect method is still used, and always will be of more or less value for purposes of comparison, especially if used with proper discrimination. A complete chemical analysis, accompanied by the density and fineness of grain enables the fusibility to be predicted with equal exactness as correct crude or careless work with the pyrometer, as has been frequently proved in the course of the work on the Missouri clays.

Physical Methods. A large number of instruments have been devised to measure high temperatures, that depend on the principles of expansion, contraction, pressure of vapors, disassociation, fusion, ebulition, specific heat, conductivity of heat, radiation of heat, spectrophotometry, wave length, magnetic moment, electrical resistance and thermo-electricity. Most of the methods and instruments are more or less unreliable, while others only give satisfactory results when manipulated by an expert physicist, and are open to serious error unless used with the greatest care. Among the latter instruments are the calorimeters and air-thermometers by the aid of which some of the most reliable determinations of high temperatures have been made; but they are entirely too delicate and need too much care in manipulation, to be adapted for every day use about an industrial establishment, though a recent design for an air-pyrometer, by Wiborgh, is said to be easily managed and reliable.

The Wedgewood pyrometer is one of the oldest and simplest ideas. It depends on the shrinkage of clay cylinders which are assumed to shrink proportionately to the increase in temperature. It is very unreliable however, as the shrinkage does not begin until the clay has been raised to a red heat, ceases when it becomes vitrified and between the two extremes the rate of shrinkage is not uniform. Different clays have very different rates of shrinkage according to the fineness of the grain and purity, while it is very difficult to mould the cylinders with sufficient homogeneity to yield concordant results even with the same clay.

An optical pyrometer, called the Lunette, designed by Nouel and Mesure consists of a small pocket telescope that contains a plate of quartz between two Nicol prisms. On looking at a body with it, one

of the Nicol prisms is revolved until the red color is extinguished by changing to yellow, then to green and finally to blue, the angle of rotation necessary to extinguish the red color varies as the temperature and therefore, is a means of roughly measuring it. But it first requires to be calibrated, while the line of color transition is not sharp, and will not only differ with the individuality of different observers, but also at different times with the same observer. It is therefore not an accurate instrument and its results are only approximations; but its speed, cheapness, and portability makes it an attractive instrument for rough work. Measurements made with it by Austin when compared with the work of the Chatelier therm-electric pyrometer show that the error, as in most pyrometers is in making the reading too high.

The melting points of metals and alloys is a type of pyrometer, that is very simple, cheap, rapid and continuous in its information, while if sufficient care is taken to make a uniform and complete set of alloys, it is amply reliable for all commercial purposes. The metals employed are noble metals, silver, gold and platinum as the base metals are liable to oxidize and so give unreliable results. Silver melts at 1,733°F., gold at 1,913° F., palladium at 2,732° F., platinum at 3,247° F. and iridium at 3,542° F. (Violle's determinations *). Any desired intermediate temperature is obtained by making up alloys of silver and platinum. If such a series of alloys are made to have melting points of 30° to 50° apart, one of the most portable, satisfactory, sufficiently accurate pyrometers is obtained. If hammered into small cubes (one-fourth to one-half of an inch in size) and so placed in the furnace that they cannot mix when melted a glance shows which are melted into a rounded globule and which retain sharp corners. When cold they can be rehammered into cubes and used repeatedly. Such a set of alloys is made by Roesler, of Frankfurt (Germany), while any desired refinement is possible by making up intermediate members of a set.

Seger claims that when there is more than 15 0 per cent of the platinum in the alloy the fusion point is not sharp, as a partial liquidation of an alloy richer in silver takes place, leaving behind a less fusible, spong-like alloy richer in platinum which melts down slowly. He therefore proposes as a substitute † a series of 20 different mixtures of kaolin and fluxes which are so made up as to have a constant differerence of 52° F., in the fusing points. He uses a very pure kaolin from Zettlitz, Austria, as a basis and gradually reduces the refractoriness by the addition of quartz, potash, feldspar, marble and oxide of iron. He

*Bull. Societe de Chemie, Tome XLVI, p. 786, 1886.

† Ibid.

makes these mixtures up into small cones, after giving each mixture a number, and observes when exposed to the fire, which numbers sag or melt. As these Seger's cones are well known, and have been considered to be very reliable for determining high temperatures, their composition is herewith given together with the temperatures at which they are supposed to melt. The cones can now be purchased at one cent each from the Royal Porcelain Works of Berlin. Seger makes up cone No. 1, to melt at 2,102° F. (or 1,150° C.) or about the melting point of an alloy of 90 per cent gold and 10 per cent platinum, while No. 20 is supposed to melt at the highest heat of a porcelain kiln or 3,092° F. (1,700 C.) All the intermediate numbers are supposed to have a constant difference in the points of fusion, or 52° F. (29° C.) Still later, other mixtures have been made running up to No. 36, for giving still higher temperatures*, while a minus set of 10, going successively from 2,100° F. to 1,680° F. (960° C.) by a constant difference of 34° F. and marked 0.1, 0.2, etc., having been proposed by Cramer*. The table is given below:

Table of Seger's Fusing Mixtures.

No. of cone.	Composition.			Fusing point.		Difference between successive numbers	
				Degrees F.	Degrees C.	In degrees	In formula.
022	0.5 Na_2O 0.5 PbO		2.0 SiO_2 1.0 B_2O_3	1310	710	36° F.	0.2 SiO_2 0.1 Al_2O_3
021	0.5 Na_2O 0 5 PbO	0.1 Al_2O_3	2.2 SiO_2 1.0 B_2O_3	1346	730	"	"
020	0.5 Na_2O 0.5 PbO	0.2 Al_2O_3	2.4 SiO_2 1.0 B_2O_3	1382	750	"	"
019	0.5 Na_2O 0.5 PbO	0.3 Al_2O_3	2.6 SiO_2 1.0 B_2O_3	1418	770	"	"
018	0 5 Na_2O 0.5 PbO	0.4 Al_2O_3	2.8 SiO_2 1.0 B_2O_3	1454	790	"	"
017	0.5 Na_2O 0 5 PbO	0.5 Al_2O_3	3.0 SiO_2 1.0 B_2O_3	1490	810	"	"

*Thonindustrie Zeitung, pp. 135-229, 1886.
*Thonindustrie Zeitung, p. 155, 1892.

No. of cone.	Composition.	Fusing points.		Difference between successive numbers.	
		Degrees F.	Degrees C.	In degrees	In formula.
016	0.5 Na_2O 0.5 PbO } 0.55 Al_2O_3 { 3.1 SiO_2 1.0 B_2O_3	1526	830	36°F.	0.1 SiO_2 0.05 Al_2O_3
015	0.5 Na_2O 0.5 PbO } 0.6 Al_2O_3 { 3.2 SiO_2 1.0 B_2O_3	1562	850	"	"
014	0.5 Na_2O 0.5 PbO } 0.65 Al_2O_3 { 3.3 SiO_2 1.0 B_2O_3	1598	870	"	"
013	0.5 Na_2O 0.5 PbO } 0.7 Al_2O_3 { 3.4 SiO_2 1.0 B_2O_3	1634	890	"	"
012	0.5 Na_2O 0.5 PbO } 0.75 Al_2O_3 { 3.5 SiO_2 1.0 B_2O_3	1670	910	"	"
011	0.5 Na_2O 0.5 PbO } 0.8 Al_2O_3 { 3.6 SiO_2 1.0 B_2O_3	1706	930	"	"
010	0.3 K_2O 0.7 CaO } 0.2 Fe_2O_3 0.3 Al_2O_3 { 3.50 SiO_2 0.50 B_2O_3	1742	950	"	0.05 SiO_2 0.05 B_2O_3
09	0.3 K_2O 0.7 CaO } 0.2 Fe_2O_3 0.3 Al_2O_3 { 3.55 SiO_2 0.45 B_2O_3	1778	970	"	"
08	0.3 K_2O 0.7 CaO } 0.2 Fe_2O_3 0.3 Al_2O_3 { 3.60 SiO_2 0.40 B_2O_3	1814	990	"	"
07	0.3 K_2O 0.7 CaO } 0.2 Fe_2O_3 0.3 Al_2O_3 { 3.65 SiO_2 0.35 B_2O_3	1850	1010	"	"
06	0.3 K_2O 0.7 CaO } 0.2 Fe_2O_3 0.3 Al_2O_3 { 3.70 SiO_2 0.30 B_2O_3	1886	1030	"	"
05	0.3 K_2O 0.7 CaO } 0.2 Fe_2O_3 0.3 Al_2O_3 { 3.75 SiO_2 0.25 B_2O_3	1922	1050	"	"
04	0.3 K_2O 0.7 CaO } 0.2 Fe_2O_3 0.3 Al_2O_3 { 3.80 SiO_2 0.20 B_2O_3	1958	1070	"	"
03	0.3 K_2O 0.7 CaO } 0.2 Fe_2O_3 0.3 Al_2O_3 { 3.85 SiO_2 0.15 B_2O_3	1994	1090	"	"
02	0.3 K_2O 0.7 CaO } 0.2 Fe_2O_3 0.3 Al_2O_3 { 3.90 SiO_2 0.10 B_2O_3	2030	1110	"	"
01	0.3 K_2O 0.7 CaO } 0.2 Fe_2O_3 0.3 Al_2O_3 { 3.95 SiO_2 0.05 B_2O_3	2066	1130	"	"
1	0.3 K_2O 0.7 CaO } 0.2 Fe_2O_3 0.3 Al_2O_3 { 4 SiO_2	2102	1150	"	"

No. of cone.	Composition.	Fusing point.		Difference between successive numbers.	
		Degrees F.	Degrees C.	In degrees	In formula.
2	0.3 K_2O, 0.7 CaO } 0.1 Fe_2O_3, 0.4 Al_2O_3 } 4 SiO_2	2154	1179	52° F.	0.05 SiO_2 0.05 B_2O_3
3	0.3 K_2O, 0.7 CaO } 0.05 Fe_2O_3, 0.45 Al_2O_3 } 4 SiO_2	2206	1208	"	"
4	0.3 K_2O, 0.7 CaO } 0.5 Al_2O_3, 4 SiO_2	2258	1237	"	"
5	0.3 K_2O, 0.7 CaO } 0.5 Al_2O_3, 5 SiO_2	2311	1266	"	1 SiO_2 0.1 Al_2O_3
6	0.3 K_2O, 0.7 CaO } 0.6 Al_2O_3, 6 SiO_2	2363	1295	"	"
7	0.3 K_2O, 0.7 CaO } 0.7 Al_2O_3, 7 SiO_2	2415	1323	"	"
8	0.3 K_2O, 0.7 CaO } 0.8 Al_2O_3, 8 SiO_2	2467	1352	"	"
9	0.3 K_2O, 0.7 CaO } 0.9 Al_2O_3, 9 SiO_2	2519	1381	"	"
10	0.3 K_2O, 0.7 CaO } 1.0 Al_2O_3, 10 Si_3O_2	2571	1410	"	"
11	0.3 K_2O, 0.7 CaO } 1.2 Al_2O_3, 12 SiO_2	2623	1439	"	2 SiO_2 0.2 Al_2O_3
12	0.3 K_2O, 0.7 CaO } 1.4 Al_2O_3, 14 SiO_2	2675	1468	"	"
13	0.3 K_2O, 0.7 CaO } 1.6 Al_2O_3, 16 SiO_2	2727	1497	"	"
14	0.3 K_2O, 0.7 CaO } 1.8 Al_2O_3, 18 SiO_2	2779	1526	"	"
15	0.3 K_2O, 0.7 CaO } 2.1 Al_2O_3, 21 SiO_2	2831	1555	"	3 SiO_2 0.3 Al_2O_3
16	0.3 K_2O, 0.7 CaO } 2.4 Al_2O_3, 24 SiO_2	2883	1584	"	"
17	0.3 K_2O, 0.7 CaO } 2.7 Al_2O_3, 27 SiO_2	2935	1613	"	"
18	0.3 K_2O, 0.7 CaO } 3.1 Al_2O_3, 31 SiO_2	2987	1642	"	4 SiO_2 0.4 Al_2O_3
19	0.3 K_2O, 0.7 CaO } 3.5 Al_2O_3, 35 SiO_2	3039	1671	"	"
20	0.3 K_2O, 0.7 CaO } 3.9 Al_2O_3, 39 SiO_2	3092	1700	"	"

No. of cone.	Composition.	Fusion point.		Difference between successive numbers.	
		Degrees F.	Degrees C.	In degrees	In formula.
21	0.3 K_2O, 0.7 CaO } 4.4 Al_2O_3, 44 SiO_2	3146	1730	54° F.	5 SiO_2 0.5 Al_2O_3
22	0.3 K_2O, 0.7 CaO } 4.9 Al_2O_3, 49 SiO_2	3200	1760	"	"
23	0.3 K_2O, 0.7 CaO } 5.4 Al_2O_3, 54 SiO_2	3254	1790	"	"
24	0.3 K_2O, 0.7 CaO } 6.0 Al_2O_3, 60 SiO_2	3308	1820	"	6 SiO_2 0.6 Al_2O_3
25	0.3 K_2O, 0.7 CaO } 6.6 Al_2O_3, 66 SiO_2	3362	1850	"	"
26	0.3 K_2O, 0.7 CaO } 7.2 Al_2O_3, 72 SiO_2	3416	1880	"	"
27	0.3 K_2O, 0.7 CaO } 20. Al_2O_3, 200 SiO_2	3470	1910	"	8 SiO_2 0.8 Al_2O_3
28	Al_2O_3, 10 SiO_2	3524	1940	"	2 SiO_2
29	Al_2O_3, 8 SiO_2	3578	1970	"	"
30	Al_2O_3, 6 SiO_2	3632	2000	"	"
31	Al_2O_3, 5 SiO_2	3686	2030	"	1 SiO_2
32	Al_2O_3, 4 SiO_2	3740	2070	"	"
33	Al_2O_3, 3 SiO_2	3794	2090	"	"
34	Al_2O_3, 2.5 SiO_2	3848	2120	"	0.5 SiO_2
35	Al_2O_3, 2.0 SiO_2	3902	2150	"	"
36	Al_2O_3, 1.5 SiO_2	3956	2180	"	"

A careful study of the original series of Seger's cones, which are herewith reproduced shows that they are open to three very serious objections. First, the main part of the mixture consists of kaolin and quartz and such a mixture has no sharp line of fusion; it gradually begins to soften, then to sag and settle, and finally to round up into a more or less rounded globule; but between the initial point of softening, or while the shape and sharp angles are still perfectly preserved and the globular or undoubtedly fused condition (though still pasty), there is liable to be a range of 200° F. or more, in passing through the various stages of viscosity. Consequently different observers are liable to make a difference of over 100° F. in deciding the point at which a given

cone fuses. This is well shown in the accompanying cut (figure 6), which is a photograph, after Hoffman, of Seger's cones which have been exposed to the same heat. While they show a sequence, the indefiniteness of any line is apparent as compared with the one unheated specimen to the right.

Figure 6. Seger's Cones after Heating.

Secondly, the cones are a mixture of fusible and infusible substances, and if not very carefully and thoroughly mixed, are liable to give very erratic and misleading results that err either way. While theoretically it is not a difficult matter to obtain a thorough mixing there is always more or less uncertainity in practice as to the uniformity of the mixture. This is well shown in the photograph of some brick clay mixtures by Hoffman (figure 7).

Figure 7. Irregularity of Cones.

A third cause of unreliability in Seger's cones is self-evident from a perusal of the formulæ by which they are made up. Remembering that Seger assumes a constant difference of fusibility between successive numbers, it will be seen that it requires only an addition of 0.1 Al_2O_3 and 1 SiO_2 to go successively from cone No. 5 to cone No. 10, while it similarly requires 0.2 $Al_2O_3 + 2 SiO_2$ to go from No. 10 to No. 14; to go from 14 to 16, it again suddenly jumps to 0.3 $Al_2O_3 +$

$3\,SiO_2$ and again to $0.4\,Al_2O_3+4SiO_2$ in obtaining the successive series from 17 to 20. Such abrupt increases in the ingredients that render the mixture less fusible certainly cannot be harmonized with a constant rate of increment in the non-fusibility of the mixture. While the error arising from this careless, approximate method of deriving the formulæ will not be large, it adds an additional uncertainty as to the probable value of the results obtained by the cones. Recent work by Hoffman with Seger's cones on clays from Ohio, Missouri and New Jersey show that they are not only inaccurate (too high) but are greatly lacking in delicacy. Hence Seger's cones are only a crude, cheap method of approximating high temperatures, and are far less reliable than the platinum series of alloys, which latter have been found to give trustworthy results by Bloss, after a recent careful series of tests, when checked with the Chatelier thermo-electric pyrometer, the Wiborgh air pyrometer, and the electrical resistance pyrometer of Hartman and Braun.

The Sieman electrical resistance pyrometer is a delicate instrument that depends on measuring high temperatures by the increased resistance that a current suffers in passing through a given wire as its temperature is raised. The wire which is preferably of platinum is exposed to the heat, the temperature of which it is desirable to determine, and a known current that is measured electrically is passed through it, and the resistance to its passage is measured by a galvanometer. It requires standardizing by an air thermometer or some other reliable means, to determine the value of the deflections of the galvanometer, and as it is found that the resistance of the wire changes it is necessary to frequently re-standardize it. If this is done it is found to give excellent results, though it is an expensive, delicate instrument that needs too much care and refinement in its manipulation in order to obtain reliable results to make it desirable around industrial establishments.

In 1887, Chatelier brought out a thermo-electric therometer that has since received his name and which has become the standard pyrometer for both scientific and practical determinations of high temperatures, as it is reliable (sensitive if necessary), quick and does not require a trained scientist to use it. It depends on the measurement of the electric current that is generated when two dissimilar metals are heated, or a thermo-pile, and although an old idea, by carefully selecting a reliable couple, and a simple, inexpensive form of galvanometer for measuring the current generated, Chatelier has developed it into a very portable, eminently practical, reliable instrument. It is open to the objection that it first requires calibrating to determine the value of

the galvanometer readings, but this is easily and quickly done, and when once determined, if the instrument is not disturbed, it holds its adjustment for months. The thermo-couple used consists of two wires, one of pure platinum and the other of an alloy of platinum with ten per cent of rhodium, which are twisted together and inserted into the furnace, the temperature of which is to be measured. The wires are so small that they take up the heat of the furnace in a few seconds and promptly give the reading corresponding thereto on the galvanometer. If desired, the wires can be left permanently in the furnace, and any variations in the temperature that may occur will at once be shown on the galvanometer. This is the pyrometer that was used in carrying on the examination of the Missouri clays in which it was found very convenient and reliable.

Chemical Methods. While it has long been known to chemists that the greater the amount of detrimental impurities in a clay, the less refractory it is, no attempt was made to put a definite value on the fluxing constituents intil the matter was investigated by the German chemists Bischof*, Richter †, and Seger ‡, who have attempted to give specific values to the chemical constituents of a clay in determining its refractoriness. Richter announced in 1868 that the fluxing impurities would have a slagging value that would be inversely proportional to their molecular weights, or that 56 of lime (CaO) would be equivalent to 40 of magnesia (MgO), or to 94 of potash (K_2O), or 62 of soda (Na_2O), or 72 of ferrous oxide (FeO), or 160 of ferric oxide (Fe_2O_3), or to 71 manganous oxide (MnO). This bold announcement is not supported by facts from the experience with the Missouri clays, and it is a very erroneous statement, as it rates magnesia as more strongly fluxing than the alkalies or ferrous oxide, whereas it is manifestly the reverse. It also ignores the form of combination in which the fluxers may be present, and overlooks entirely the influence of density and fineness of grain.

Bischof endorses Richter's law (page 43), and from experiment made on variable mixtures of silica and alumina is so deeply impressed with the greater fusibility of the mixture as the silica is increased (up to a certain limit) that he makes the remarkable statement that silica is as detrimental as the commonly rated fluxers (iron, lime and the alkalies) in affecting the fusibility of a clay. As a result of his studies he comes to the conclusion that the refractoriness of a clay will be:

(1) Proportional to the alumina to the fluxes, and

* Die Fuererfesten Thone, p. 71, Leipzic, 1876; also Dingler's Journal, vol. CLXV, p. 378.
† Dingler's Journal, vol. CXCI, p. 59, 1868.
‡ Thonindustrie Zeitung, 1877, p. 290; *Ibid.* 1889, p. 332; *Ibid.*, 1893, p. 339.

(2) Proportional to the alumina to the silica.

This is expressed in a formula which he calls "F. Q." or the "Feuerfestigkeitsquotient," and is as follows:

$$F. Q. = \frac{\text{Alumina} \times \text{Alumina}}{\text{Fluxes} \times \text{Silica}} = \frac{Al_2O_3 \times Al_2O_3}{RO^* \times SiO_2} = \frac{(Al_2O_3)^2}{RO \times SiO_2}$$

With this formula as a basis he has classified fireclays into seven types or groups, in which the most refractory has a value for *F. Q.* of 14, and the least refractory that is used for fire-brick has a value of 1.6. While these values are purely relative and will be found on consulting the analyses of these type clays to have no regular order or sequence they are valuable for purposes of comparison. It is a very important step forward in thus utilizing the chemical analysis of a clay to definitely determine its pyrometric value, and Bischof is entitled to the gratitude of the chemist and clay-worker for this decided advance; but unfortunately, like most pioneer efforts, the problem is far more complicated and, as will subsequently be shown, very serious errors are liable to result from using it. At the time Bischof evolved this formula silica was written SiO_3 (as also in Seger's formulæ) which will have to be considered in arriving at the values for F. Q. given by Bischof.

Seger in 1877,† criticised Bischof's formulæ and suggested that the refractoriness is not proportional to the square of the alumina, nor does it decrease directly with the increase of the silica. He does not think it depends solely on the relation which the silica bears to the alumina. He offers as a substitute for Bischof's formula the following as being a more reliable index of the refractoriness of a clay:

$$S. F. Q. = \left(\frac{Al_2O_3}{RO} + \frac{SiO_2}{RO}\right) \times \left(\frac{Al_2O_3}{RO} \div \frac{SiO_2}{RO}\right)$$

Seger's formula is a great improvement over Bischof's and gives more reliable results, but it still ignores the vital questions of density, fineness of grain, and mode of combination of the impurities, while an equal fluxing value is given to all of the impurities.

On comparing the values given by Seger's formula with those by Bischof, in the analyses of Bischof's seven type clays, which are herewith reproduced, they give far more harmonious and close approximation values to types, 4, 5, 6, and 7, which, if the analyses are correct and made on reliable samples, cannot have the relative sequence that Bischof's formula gives. Type 5, the Grundstadt fireclay, has nearly 7.0 per cent of detrimentals, of which over 3.0 per cent are alkalies, yet

*RO represents the fluxes or detrimental constituents.

† Thonindustrie Zeitung, pp. 290-296, 1877.

Bischof's Seven Types of Fireclays.

	I. *Saarau, Selesia.* (Coal measures.) (Very lean.)	II *Zettlitz, Bohemia.* (Kaolin) (Lean)	III. *Ardenne, Belgium.* (Coal measures.) (Very fat.)	IV. *Coblenz, Germany.* (Cretaceous) (Very fat)	V. *Grunstadt, Germany.* (Tertiary.) (Fat.)	VI. *Cassel, Germany.* (Cretaceous) (Very fat)	VII. *Neiderpleis, Nassau.* (Cretaceous) (Very fat.)
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Moisture at 212° F.	3.26	8.90	10.73	10.46	7.43	6.88	6.55
Silica, combined	38.94 } 43.84	40.53 } 45.68	39.69 } 49.64	41.00 } 47.74	39.32 } 47.33	33.59 } 57.99	30.71 } 58.32
Silica, as sand	4.90	5.15	9.95	6.74	8.01	24.40	27.61
Alumina	36.30	38.54	34.78	36.00	35.05	27.97	28.05
Ignition loss	17.78	13.00	12.00	11.81	10.51	9.43	8.66
Total non detrimentals	97.92	97.22	96.42	95.55	92.89	95.39	95.03
Oxide of iron	0.46	0.90	1.80	2.57	2.30	2.01	1.89
Lime	0.19	0.08	0.68	0.40	0.16	0.97	0.72
Magnesia	0.19	0.38	0.41	0.33	1.11	0.54	0.75
Potash (mainly, also soda)	0.42	0.66	0.41	1.05	3.18	0.53	1.39
Total detrimentals	1.26	2.02	3.30	4.35	6.75	4.05	4.75
GRAND TOTALS	99.18	99.24	99.72	99.90	99.64	99.44	99.78
1. Bischof's F. Q.	*13.95*=100	*9.40*=65	*4.21*=50	*3.96*=45	*2.37*=30	*1.86*=20	*1.64*=10
2. Segers F. Q.	33.15	22.31	11.08	9.97	6.03	6.27	5.54
3. Wheeler's F. F.	56.3	36.9	26.0	17.7	9.4	20.9	15.5
4. Uses	Steel crucibles. Glass pots.	Porcelain.	Retorts (zinc). Crucibles.	Zinc retorts. Glass pots.	Glass pots Furnace blocks.	Firebrick.	Firebrick.

Bischof rates it as 30:20, when compared with type 6 or the Cassel fireclay which has only 4.5 per cent detrimentals, of which 0.53 per cent are alkalies; yet on this basis type 6 must be decidedly more refractory than 5, and type 7 is also undoubtedly more refractory than 5. Unfortunately no reliable pyrometric determinations have been made on Bischof's type fireclays, as far as known, to that no positive statements can be made as to their relative refractoriness. As Bischof's formula has been quite generally accepted and has only been questioned by Seger who modifies it to an important but still insufficient extent, it is worthy of careful consideration.

Bischof states that the refractoriness of a clay is directly as the square of the alumina, and inversely as the silica and the fluxes, or

$$F.Q. = \frac{(Al_2O_3)^2}{SiO_2 \times RO}$$

in which RO represents the fluxes or detrimental constituents which are assumed to be present in the condition of protoxide, which is usually the case except with iron, which latter is often present as the much less fusible sesquioxide, in yellow and red clays.

As the basis of successful metallurgical practice depends on a thorough acquaintance with the relative fusibility of slags, which are silicates, the experience of the metallurgist will at least be of great aid in studying the relative fusibility of clays. From his furnace practice with slags, the metallurgist finds: (1) That while an increase in the percentage of alumina decreases the fusibility, when it becomes very high it acts the part of an acid instead of a base and tends to lower the fusing point instead of raising it, which is quite the reverse of Bischof's formula, when this point is reached; neither does the fusibility decrease when the alumina is in moderate amounts, at the rapid rate of the square of the alumina; (2) when the silica is present in amounts greater than a mono-silicate (which is always the case with clays) the fusibility decreases as the silica increases, which is just the reverse of Bischof's formula; yet this is one of the best and most conclusively established facts in metallurgy; (3) as a broad rule, the fusibility increases as the bases increase, at least to the extent that they occur in clays; but there is a very great range in the fusibility according to the bases that are present. The alkalies are more readily fusible than the ferrous oxide, which latter is more fusible than lime, and lime more fusible than magnesia. Again a mixture of bases is more fusible than a single base, and the greater the number of bases the greater the fusibility. Bischof's formula, however, pays no attention as to the bases present, or how many, though usually lime, iron, magnesia, and the alkalies are present in all clays to some extent. As the above ex-

perience of the metallurgist with slags covers a very wide range of silicates, though they are more basic, less aluminous and less silicious than clays, it at least throws very grave doubts on the reliability of Bischof's formula.

Turning for further evidence to mineralogy there is in the feldspar group of minerals a most interesting series of silicates that have a composition closely resembling the impure clays, and from which all clays were originally derived. The following table is taken from Dana:

Fusibility of the Feldspars.

Name.	Character.	SiO_2	Al_2O_3	K_2O	Na_2O	CaO	FeO	H_2O	Total RO	Fusibility.
Orthoclase. ..	Tri-silicate..	64.7	18.4	16.9	....	.....	....	.....	16.9	5.0
Albite..........	Tri-silicate........	68.7	19.5	.....	11.8	.....	.....	.....	11.8	4.0
Oligoclase	¾ tri-silicate... ¼ bi-silicate ...	63.0	24.0	2.0	9.0	3.0	....	.....	14.0	3.5
Labradorite ...	Sesqui-silicate ...	54.0	29.0	.....	5.0	11.0	1.0	.....	17.00	3.0
Anorthite.	Mono-silicate.....	43.2	36.7	....	....	20.1	.....	.....	20.1	5.0
Kaolin....	⅔ mono-silicate ⅓ bi-silicate ...	46.3	39.8	.....	......	.....	.....	13.9	0.0	7.0

The scale of fusibility is von Kobell's well known scheme for comparing minerals, which, though crude, at least gives a good relative idea. From a study of this table it will be seen that the least silicious feldspar, anorthite, is the most infusible, while labradorite, one of the most aluminous, is the most fusible, which is the reverse of what would be expected from Bischof's formula; the latter feldspar, moreover, has 17.0 per cent of RO, as has also the least fusible feldspar orthoclase, which shows that it is not a mere question as to the amount of RO or proto-bases present. The table very clearly shows that the primary consideration in this case, as regards fusibility, is the number and kind of bases present; for the most fusible feldspar, labradorite, has lime, soda, and iron, or three RO bases; and the next most fusible, oligoclase, has lime and soda, while the other three feldspars have each only one RO base (CaO).

The strong similarity in composition between the feldspars and clays, together with the fact that all clays were originally derived from the feldspars, renders this mineralogical evidence of very great value, in showing theoretically the unreliability of Bischof's formula.

Turning to positive evidence for testing the value of Bischof's formula, or by actual trial, it will be observed in the table that the values of *F. Q.*, or the relative fusibility, are grossly erroneous and gravely

misleading in many cases both as regards similar and dissimilar clays. Thus, it gives about the same rating for a shale that fails at 2,000° F. (Louisiana, Missouri, No. 32 p. 151), as for a potters' clay that fails at 2,350° F. (Commerce, Missouri, 23), and for a very refractory fireclay that fails at 2,700° F. (Parker-Russell, 7). Again, it rates higher, or at 5.4 a fireclay (Sattler, mine-run, 6) that yields at 2,500° F., while a similar fireclay from the same vein that fails at 2,700° F. is rated at 2.6 (No. 7). An infusible, very silicious kaolin (Cape Girardeau, 19) is rated at 0.4, while an exceptionally easily fusible shale (Kansas City, 30) is rated higher, though it melts at the very low heat of 1,900° F. A further perusal of the calculated ratings by Bischof's formula, as compared with the pyrometic tests, show many other glaring errors, especially in the excessively high ratings of the flint clays. The unreliability of Bischof's formula arises partly from its faulty construction, partly from the faulty weighing of the detrimental constituents, and partly from ignoring the physical factors. The latter fault is very serious, if clays differ much in density or fineness, but when these physical properties are similar, then it is possible to compare the fusibility of two clays solely from the analyses, if the proper valuations are given to the constituents.

In attempting to arrive at a reliable formula for deducing the refractoriness of a clay from the chemical analysis, there appears to be little satisfactory evidence that silica (free or combined), alumina, combined water, moisture, or titanic acid have any deleterious influence whatever. Should the titanic acid be high, or exceeding five per cent, it is possible that it might act detrimentally; but in the small amount that was found in the Missouri clays, or less than two per cent, its influence could not be detected. While Seger states that silica decreases the refractoriness of a clay the very siliceous Missouri kaolins gave no evidence of being rendered more fusible in consequence of their large amount of silica, nor did those fireclays that were exceptionally high in silica. These constituents can therefore be regarded as nondetrimental and are so treated in the subsequent formulæ.

The detrimental constituents were found to be those that are almost universally considered so by chemists, the alkalies, ferrous and ferric oxides, lime and magnesia. Of these the alkalies were found to be decidedly the most severe in their fluxing action, which corresponds to the experience of the metallurgist and chemist in making slags and fusions. Of the two alkalies it is probable that soda is the more objectionable and a mixture of both is more severe than either alone; but insufficient data prevented any nice determinations

on this point, which is not important in view of both being nearly always present in most clays and the alkalies are not usually separated in commercial analyses. Ferrous oxide was found to be almost, if not quite, as severe in its slagging action as the alkalies; but as in the slow water-smoking stage that most clay ware is subjected to, the ferrous oxide usually oxidizes up into the higher or ferric oxide, which is very much less fusible. The iron is regarded as always occurring in the form of the less fusible ferric oxide, as since that is its usual condition before a fluxing temperature is reached. There does not seem to be a marked difference between ferric or sesquioxide of iron, lime and magnesia in their fluxing values, so they are added together and rated as having half the fluxing value as an equal amount of the alkalies. Further work is needed on this question, as the metallurgist and chemists find that magnesia is the least, and ferric oxide the most fusible of these three fluxers, but the work on the Missouri clays did not enable any safe conclusions on this question to be drawn, so they are provisonally given equal value. Further investigation may probably differentiate their action to at least a slight extent.

In deducing a formula for the relative refractoriness of clays it is believed that the old rule of the chemist is reliable, that the greater the amount of the fluxing impurities the more fusible is the clay, provided the clays are similar in fineness and specific gravity, and a double allowance made for the alkalies. Expressed as a formula the following is offered as expressing the fusibility factor, or a numerical value for the relative refractoriness, of a clay which is the more refractory the higher the value:

$F. F. = \frac{N}{D+D'}$, (*A*) when the clays have the same specific gravity and fineness of grain.

In this formula *F. F.* represents numerical value of the refractoriness. N represents the sum of the non-detrimental constituents, or the total silica, alumina, titanic acid, water, moisture, and carbonic acid. D represents the sum of the fluxing impurities, or the alkalies, oxide of iron, lime and magnesia. D′ represents the sum of alkalies, which are estimated to have double the fluxing value of the other detrimentals and hence are added twice.

This formula is found to give fairly good comparative values of the refractoriness of clay that do not differ more than 0.2 from one another in density (the closer the specific gravity the more reliable the comparison), and are of similar fineness of grain. When the clays to be compared differ in density and fineness it is necessary to modify

Table showing the value of Calculated Fusibilities of some Missouri Clays.

No.	Name.	SiO_2	Al_2O_3	H_2O	Total N...	D'alkalies	Total D'..	Sp. Gr. ..	Grain.	Fusibility.			Bischof.	Wheeler.	
										Incip.	Complete	Scoria.	F. Q.	A.	B.
	ST. LOUIS FIRECLAYS.														
1..	Christy, washed	64.35	21.16	8.94	94 45	0 51	4.81	2.13	Fine	2200°	2400°	2700°+	3.3	17.7	13 0
2..	" mine run........	61.73	23.56	9.25	94.54	1.00	7.30	2.47	Coarse.........	2100	2300	2500	2.7	11.4	10.2
3..	Jamison, washed	58.61	27.36	11.13	94.10	0 71	5.25	1.92	"	2200	2400	2700	5 4	15.8	11.8
4..	" mine run.	53.90	28.85	11.61	94.36	0.85	6 86	2.40	"	2200	2400	2600	4.7	12 2	10.9
5..	Sattler, washed	52.98	28 77	11 42	93.17	1 01	5.12	....	Fine	2200	2100	2700	5.3	15.2	11.4
6..	" mine run.........	51.66	30 78	11.86	94 30	0.99	5.88	2 40	"	2100	2300	2300	5 4	13.7	10.6
7..	Parker-Russell	67.47	19.33	7.73	94.53	1 07	5.14	2.44	Very coarse....	2250	2450	2700	2.6	13.2	13.3
8..	Laclede	57.34	24.69	11.55	93.57	0 67	6.30	2.45	Coarse	2250	2450	2650	4.2	12.9	11.1
9..	Evens & Howard	59.36	23.26	10.20	92.82	0.63	5 67	2 41	"	2250	2150	2630	3.4	12.9	11.3
	FLINT, OR NON-PLASTIC FIRECLAYS.														
10..	Pendleton	46 18	38 12	14 01	98 31	1 20	2.06	2 42	Fine	2300°	2500°	2700°+	32 0	28 0	18 0
11..	High Hill.	45.12	40.46	13.34	98.92	0 30	1.06	2 33	Very fine	2350	2550	2700+	48 0	73.0	29.0
12..	Drake	40.50	43 22	14.15	97.87	0 51	1.93	2.35	"	2300	2500	2700+	47.0	40.0	22.0
13..	Truesdale	43.56	41 48	14.05	99 09	0.20	1 00	2 45	"	2300	2500	2700+	72.0	82.0	31.0
14..	Union	44.14	39.86	13.84	97.84	0 76	2.45	1.98	Fine	2200	2400	2700	24 5	31.0	18.0
15..	Owensville................	44.70	35 92	12.62	93.24	0.29	6.55	....	"	2050	2200	2850	7.1	11.0	9 0
16..	Sankeys......	50.18	33.03	11.68	95.07	2.06	5 29	2.10	Coarse....	2100	2300	2500	7.8	13.0	10.0

KAOLINS.

17..	Glen Allen	72 80	18.94	7.04	98.28	0.42	1.89	1.89	Very fine......	2200°	2400°	2600°	4.0	42.0	15.6
18..	Sterling	57.75	27.60	11.43	96.78	0 60	8 24	....	"	2200	2400	2600	8 0	28.0	12.3
19..	Cape Girardeau......	91.05	5.01	2.74	98.8	0.12	1.27	2.02	"	2200	2400	2600+	0.4	70.0	22.0
20..	Winona	56.74	27.29	7.40	91 43	1 21	8.52	1.86	"	1800	2000	2200	3 2	9.6	7.0

POTTERS' CLAYS.

21..	Guthrie...........	47.13	34.98	13 88	93.99	0.52	3.76	2.18	Very fine......	2000°	2200°	2400°	12.0	22.0	13.0
22..	Mammoth	49.04	34.85	12.33	96.22	0 85	3.93	1 69	"	1800	2100	2400	9 1	20.0	11.0
23..	Commerce.................	71.78	17.01	8.13	96.92	0.78	3.56	2.03	"	1950	2150	2350	2.1	22.0	13.0
24..	Clapper (fireclay).	67.76	21.96	8.23	97.95	0.24	2.43	2.45	Coarse.........	2500	2700	2700+	5.7	46.0	27 0
25..	Deepwater.	74.02	15 26	3.69	92.97	2 37	5.38	2.37	Fine...........	2100	2300	2500	1.2	12.0	10.6

BRICK CLAYS (LOESS).

26..	Kansas City....	72.00	11.97	6.42	90.19	3.25	10.11	2.17	Fine	2000°	2200°	2300°	0.3	6.8	5.7
27..	Hartwell.......	60.93	21.51	5.30	87.64	2 03	10.15	1.80	"	1850	2050	2150	1.4	7.2	5.4
28..	St. Louis............. ...	73.92	11.65	5.26	90.83	3.18	9.90	1.98	"	1800	2000	2100	0.4	6.8	5.3

SHALES.

29..	Moberly	65.01	19.30	6.54	90.85	2.60	9 31	2.41	Coarse.	1850°	2050°	2250°	1 3	7.5	7.0
30..	Kansas City...............	54.80	23.73	6.00	84 53	3.80	15.34	2 37	Very fine......	1500	1700	1900	1 4	4.4	4.0
31..	Deerfield..................	58 90	21.38	8.69	88.97	1.52	10.84	2.43	Medium	1800	2000	2200	1.3	7.3	6.5
32..	Louisiana.................	57.01	24.43	7.63	89.07	3.81	11.47	2.39	Coarse.	1600	1800	2000	2.0	5.8	5.5

formula (A) by a constant C that will have different values depending on the density and fineness, so that the formula will be:

F. F.$=\frac{N}{D+D'+C}$ (B) in which N, D, and D′ will have the same values as in (A).

C=1, when clay is coarse-grained and specific gravity exceeds 2.25.
C=2, when clay is coarse-grained and specific gravity ranges from 2.00 to 2.25.
C=3, when clay is coarse-grained and specific gravity ranges from 1.75 to to 2.00.
C=2, when clay is fine-grained and specific gravity is over 2.25.
C=3, when clay is fine-grained and specific gravity is from 2.00 to 2.25.
C=4, when clay is fine-grained and specific gravity ranges from 1.75 to 2.25.

These values of C are only approximate, as not enough work was done on a sufficiently large variety of clays to give satisfactory values, while no simple method was arrived at for giving a ready and correct expression of the fineness. Still enough work was done to show that formula (B) is the only one that can be used indiscriminately on all kinds of clays, though a very large amount of work has still to be done to arrive at more reliable values for C, and the fineness, as the large number of factors involved make it a very complex question.

In the preceding table examples have been selected from 110 samples of the Missouri clays that have been completely studied, which illustrate the utter unreliability of Bischof's formula, the quite satisfactory comparative values given by formula (A) on clays that are physically similar, and the much more general scope of formula (B) which considers physical as well as chemical influences, though it also shows the need of further work to obtain more reliable values for the constant C. Thus, in the St. Louis fireclays, which are all obtained from the same seam, Bischof's formula gives about equal values to clays of very different fusibility (Nos. 1 and 2) and very different values (1.08 to 3.44) to clays of about equal fusibility (Nos. 5 and 7.) The Cape Girardeau kaolin, No. 19, with 91.05 per cent of SiO_2 and 1.27 per cent of fluxes is given a very inferior value for its refractoriness by Bischof, or 0.4, though as the analysis indicates it could not be affected by the highest heat of the furnace; while the easily fusible Winona kaolin, No. 20, is given the higher value of 3.2. Again the Clapper clay, No. 24, which is one of the most, if not the most, refractory clays known, is given a value of only 5.7 by Bischof, while the Owensville clay, No. 15, has a value of 7.1, though it fuses at 2,350° F.

A refractory clay, or one capable of withstanding 2,500° F. should have a value of 12 or over, when calculated by formula (A), for coarse, very dense clays; or exceed 10, when using (B); and the higher the value of *F. F.* the more refractory a clay is.

It should be remembered, in using either formula that it is still premature to make very delicate distinctions, as the determinations

were not made closer than 50° F. On account of the poor conducting power of clay it is difficult to determine its exact temperature, as differences of 100° F. were found within one-half inch on the same bricklet. Furthermore, for practical purposes it is impossible to control or maintain furnace temperature within such a narrow range as 50° F.

CHAPTER VIII.

THE CHINA-WARE CLAYS.

Under the broad term of "China-ware" is included "queensware" (both plain and decorated), cream-colored or "C. C." ware, granite-ware, sanitary-ware, iron-stone china, French china, parian, wedgewood-ware, belleck, porcelain, both soft and hard, and the other varieties of high grade ceramic ware that have a white or light-colored body. Clays that are suitable for making the body of this large variety of pottery are called the China-ware clays. Under this term are included kaolin, cornish-stone, porcelain-clay, china-clay, ball-clay, bond-clay, pipe-clay, and potters' clay, or those clays which are sufficiently free from coloring impurities (or can be readily freed therefrom) as to give a white or very light colored body after being fired in the kiln. Although these different kinds of clay, from the potters' standpoint, differ from one another almost as much as the different varieties of pottery that are included in the broad term of china-ware, they possess certain well defined chemical properties in common that makes it desirable to consider them as a group by themselves.

CHEMICAL REQUIREMENTS OF CHINA-WARE CLAY.

The salient characteristic of the china-ware clays is their practical freedom from coloring impurities, which are usually different compounds of iron (the oxides, sulphide, carbonate, silicate and sulphate). Occasionally manganese, with its browns and blacks, or titanium with its blues and purples, also prevent clays being used for china-ware. While no clays are absolutely free from iron, many contain so little as to burn to a white or slightly cream-colored body after firing in the kiln; the less iron present the whiter is the burnt ware. The amount that can be tolerated depends not only on the purpose for which the clay is used, but also on the amount of lime and magnesia present, both of which tend to neutralize and destroy the coloring action of the iron. For high grade ware as porcelain, parian and belleck, the iron (or manganese) should not exceed 0.5 to 1.0 per cent, while "queensware" and goods of lower grade can bear 1.5 to 2.0 per

cent* of iron (or manganese) when calculated as the sesquioxide (Fe_2O_3). More iron can be tolerated if the lime and magnesia present exceed 3.0 per cent or preferably 5.0 per cent, on account of bleaching action. The titanium can probably exceed 3.0 per cent before its presence becomes objectionable from the blue to purple tinge it tends to give when the clay is burnt very hard.

A second but much less important requisite of china-ware is that the other basic impurities, as the alkalies (potash and soda), lime, and magnesia should be present in the form of the silicates. If they are present in the other usual forms of sulphate or carbonate they may cause the ware to blister, or "frizzle" in burning in the kilns from the expulsion of the SO_3 or CO_2 gases at a high heat, when the outside of the ware may be in a pasty condition. By burning the ware very slowly so as to give the gases time to escape before the ware begins to soften, this will not happen, and chalk (carbonate of lime) and gypsum (sulphate of lime) are even added as "softners" or to render the mixture more fusible, in some glazes and soft porcelain. The influence of such impurities as sand in the china-ware clays affects the plasticity and drying qualities, as the more sand the less plastic but the more rapid the drying. The fluxing impurities, as the alkalies, lime, magnesia and iron, greatly modify the heat at which the ware is burned, permitting it to be done at lower temperatures as they increase in amount. The fusing point is not so vital in the china clays, however, as in the refractory clays, as by the use of "spar" (feldspar), fritte and bone-ash, the clays are rendered more fusible, while by the use of "flint" (quartz), burned clay and by coarse grinding they are made less fusible.

From the chemist's standpoint the china-ware clays usually are the more valuable the nearer they approach the composition of kaolinite, or

Silica (SiO_2)	46 3 per cent.
Alumina (Al_2O_3)	39 8 per cent.
Combined water	13.9 per cent.

which is almost the analysis of the Cornish kaolin, and if the physical properties of clays were similar the analysis would be an excellent guide for judging of the value of the china clays. But clays differ so greatly in their physical properties, even when the composition is similar, that an analysis is valuable only for indicating the probable color of the burned ware from the amount of coloring impurities present, and the absence of objectionable sulphates and carbonates. The very important questions of plasticity, shrinkage, rapidity of drying and

*By using 0.01 to 0.08 per cent oxide of cobalt, larger amounts of iron can be neutralized, by the blue tendency of the cobalt overcoming the yellow of the iron, on the same principle that bluing is used in washing to render linen white.

burning, and even the fusibility of the clay (within certain limits) have to be determined by physical tests. Thus the High Hill, Missouri, rock-clay which is almost a pure kaolinite is valuless as a china-clay, because it is non plastic and shrinks excessively in burning (10.0 per cent), while the Glen Allen kaolin is very valuable for china-ware, though it does not contain 50.0 per cent of kaolinite or the base of clays, as sand or free silica constitutes 51.0 per cent. The Brooks kaolin, of Cape Girardeau, Missouri, has 85.0 per cent of sand; but on account of this extreme amount of sand is "very lean" or but slightly plastic, and is really an aluminous, very fine sand rather than a very sandy clay. This excess of silica or sand is not only very characteristic of the Missouri kaolins, but is usually the rule in the general occurrences of kaolin throughout the world. The comparatively small value of the chemical analysis of a china-ware clay, as it gives but a slight clue to its physical properties, is well shown by the wide range in composition that is found in these clays, as given in the following table:

Range in Composition of China-ware Clays.

	Per cent.
Combined water	2 0 to 14 0
Silica	45.0 to 85.0
Titanic acid	0.0 to 3.0
Alumina	5 0 to 40.0
Sesquioxide of iron	0.0 to 2 0
Lime	0.0 to 2.0
Magnesia	0 0 to 1.5
Alkalies	0.0 to 3.0

The combined water as given in many samples is often greater than one-third of the alumina, as the organic matter, carbonic and sulphuric acids, or other substances that are liable to be present and which are volatile at a high heat, are driven off with the combined water, and reported as such, in the absence of special determinations, and hence give an erroneously high value to this so-called combined water. An error also sometimes appears in the alumina, as given in most commercial analyses, from not determining the amount of titanic acid present, which often exceeds 2.0 per cent; and in some methods of analysis it is reported as alumina, though more usually as silica. The higher the combined water and alumina, between which there is usually found a constant ratio of 1 to 2.9, the more plastic or "fat" a clay, generally is, as it indicates the kaolinite or the plastic base of the clay while the fire-shrinkage correspondingly increases with this evidence of the purity of the clay which the two substances indicate. The higher the silica, the "leaner" or less plastic is the clay, as it shows the presence of sand or feldspar, and the fire-shrinkage is cor-

respondingly decreased from the presence of this foreign, non-shrinkable matter. But excessive amounts of sand or feldspar, unless uniformly mixed throughout the clay, greatly increase the risk of cracking and crazing in drying and burning, because of the variations in the shrinkage that their unequal distribution causes.

The iron greatly affects the color of the burned clay, producing cream to buff colors when amounting to 1.0 to 3.0 per cent, and browns, reds or blacks when exceeding 3.0 per cent. Its coloring action is neutralized in the potteries by the use of "spar," flint, bone-ash and cobalt, so that some clays with as high as 3.0 per cent of sesquioxide of iron are used to a slight extent in mixtures, though the less iron the better in all china-ware clays. Iron also increases the fusibility of a clay. Titanic acid affects the color of a hard-burned clay, if exceeding 3.0 per cent, but as clays seldom contain this amount it is not usually determined in commercial analyses. It produces blue and purple colors that are only developed when burnt at a high heat. Lime and magnesia are frequently absent in china-ware clays and if present as silicates, when they are probably combined in the feldspars, there seems to be no objection to them. On the contrary, as they render the clay more fusible, and tend to neutralize the coloring action of iron, they are advantageous in most cases, though they are rarely found in china-ware clays exceeding the limits given in the previous table.

The alkalies (potash and soda) increase the fusibility of the clay and are therefore advantageous in varieties that are to be used for vitrified ware, by enabling the vitrification to be done at lower temperatures. They also increase the strength of the burned wares, if not cooled too rapidly in the kiln. They are nearly always present, combined in the feldspars, which latter are rarely absent and usually vary from 0.5 to 2.5 per cent, though some of the Japanese kaolins have as much as 7.0 per cent.

REQUISITE PHYSICAL CHARACTERS.

Physically the china-ware clays differ from other clays in usually being white or light gray in color, though occasionally they are discolored by organic matter, when they are more or less dark to black in color, very rarely red. The black in this case disappears on burning. They are never yellow, brown or green and very seldom red, as these colors are caused by the presence of large amounts of iron. Still, all light gray or even white clays may not be sufficiently low in iron to answer for the china-ware, as they may have large amounts of pyrite (or "shiners") which may be in such a fine state of division as to pre-

vent its successful removal by washing, though very prolonged weathering is likely to more or less completely remove it (by oxidation and leaching).

The china-clays have usually a much finer grain than other clays, though this is less characteristic than the light color. In plasticity the china-clays vary from "very lean" or slightly plastic to plastic, and seldom show that very high degree of plasticity that is frequently found in the fireclays, brick clays and some shales; but by careful and thorough working they are rendered much more plastic than as they occur naturally, and are then capable of being successfully moulded into the most intricate and delicate shapes.

CLASSIFICATION OF CHINA-WARE CLAYS.

The china-ware clays are divided by the potters into two classes that have quite distinct properties, and usually a marked difference in the mode of occurrence, or into Kaolins and Ball-clays.

Kaolins. These, including kaolinite or pure clay, "cornish stone," or more or less decomposed feldspar, porcelain clay, and usually china clay, are light, soft, porous, amorphous, usually lean, generally white clays that are found at or near their points of origin. Generally the granitic rocks are the origin of kaolin, as they mainly consist of feldspar with small amounts of quartz, mica and other minerals, and when they are exposed to the action of air and water, especially when aided by frost, the feldspar undergoes the peculiar change known as kaolinization, or is changed into the mineral kaolinite, the base of all clays. As this zone where the rocks are jointly subjected to the chemical action of air and moisture is usually at or near the surface, kaolin beds change, on reaching the permanent water level to the hard, tough, unaltered rock. In the very arid regions of the Far West, this zone of alteration and decay sometimes extends to great depths, from 100 to 1,000 feet below the surface. If the granite or other rock by whose decay or kaolinization the clay has been formed is free from hornblende, augite, magnetite and other iron-bearing minerals, the clay produced is a white, soft, very fine-grained, porous, somewhat plastic, amorphous mass and is commercially known as kaolin. But if iron-bearing minerals are present the resulting clay is more or less red or yellow to brown-stained or streaked, and thereby probably ruined for china-ware purposes, and is known as common clay. Intermixed through the clay or kaolin are the quartz grains of the granite that have now been set free or liberated as loose fragments in the kaolin, and also more or less extremely fine silica, as the excess that has been left uncombined in the change of the feldspar into kaolinite. There may be other resistant

minerals as magnetite ("black sand"), rutile and zircon, that is also left as disseminated grains of sand, while often there are also fragments of harder and more resistant portions of the original rock mass. Hence such a kaolin requires washing to remove the associated detrimental minerals, and by active agitation in an excess of water the very fine kaolin is held in suspension and floated off—leaving behind the heavy, more or less coarse sandy particles and fragments. Where nature has done this through the action of rains, and redeposited the fine clay in beds at the base of the hills or mountains there is found more or less kaolin, free from the coarse, sand-like impurities, and sometimes enough for use without further washing. Thus from the origin of the kaolin it is usually found at or near the surface, under usually a light cover or stripping. The lack of any great overlying weight to consolidate it is the reason that it is so soft, porous and amorphous.

The existence of kaolins, *in situ,* close to their points of origin, also explains the reason why they are usually so "lean," or have their plasticity so poorly developed. For they are not only usually loaded with an excess of free silica from the mechanical disintegration of the rocks and the chemical decomposition of the feldspar, which being non-plastic acts as a diluent, but there has not been enough of mechanical action to sufficiently break up the crystalline plate structure of the kaolinite, and unless this is done pure kaolinite is non-plastic.

Ball Clays. The Ball clays, which include also the white variety of "pipe-clays," the better grades of bond and potters' clays, and plastic china-clays, are plastic clays that are used as a bond or bonding material for incorporating kaolin, feldspar, "flint" "grog" and other lean or non-plastic material into the body of china-ware. They differ from what the trade calls kaolins, in having a highly developed plasticity, are usually less silicious and more aluminous, and are often hard and compact, until ground up with water, which brings out their plasticity. They usually occur at a long distance from their places of origin and are deposited as more or less regular beds, lenses, or pockets on rocks that are in no way connected with their origin. The mechanical disintegration resulting from the comminuting action of transportation has ground the lamellar kaolinite crystals so fine as to develop their plasticity, which is lacking in the kaolins. They are often buried under other deposits, whose weight has consolidated them into more or less hard, compact, dense, massive bodies, sometimes with the development of joint and bedding planes, while they are free from the coarse granules and fragments of quartz and undecomposed rock that are so often found in kaolin beds. While the ideal kaolin bed rests as an amorphous mass directly on the parent granite below and the typical ball-clay

occurs in stratified bodies at a great distance from the granitic or other rocks from which it has been derived, the two classes merge into each other in both chemical and physical properties, as there is no sharp line of demarkation between the kaolin that has slid or washed to the foot of a hillside on which it was formed, and the more distantly removed ball-clay that may have been deposited one mile or five hundred miles from its source, but the greater the distance it is transported the finer it will be ground, and the more plastic it is thereby rendered, while it is less silicious from leaving behind the coarser sand particles. The fine clay particles remaining so much longer in suspension are liable to become contaminated with impurities especially with iron salts, so that it is very exceptional for very plastic clays to be pure enough to answer as "ball" or "bond" clays for china-ware. Hence there will be an indefinite series of china-ware clays that vary from the light, soft, porous, amorphous, usually white, silicious kaolin, at one extreme, to the dense, hard, compact, massive, usually gray, aluminous ball-clay at the other extreme, and the term "china-clay" could very appropriately be applied to such clays that are midway between these extremes, or those soft, white plastic clays that are not fat enough for a good bonding clay, yet possess sufficient plasticity to be worked alone into china-ware.

KAOLIN DEPOSITS OF MISSOURI.

All the kaolin thus far found in Missouri occurs south of the Missouri river on limestones of Paleozoic age. The belt containing it is extensively worked in Cape Girardeau and Bollinger counties, in the southeast, from whence it extends to Howell county, forming the southeastern kaolin district. It is also worked, but much less extensively, in Morgan and Cooper counties, in the central part of the state, which is called the central district. It is found, though thus far not worked, near Aurora, in Lawrence county, which is known as the southwestern district. In the latter district, which is probably very limited, the kaolin occurs in association with limestones of lower Carboniferous or Mississippian age. In the central district the kaolin is associated with the upper members of the Ordovician limestones, and in proximity to the lower Carboniferous. In the southeastern district, the kaolin is associated with limestone of the Ordovician and Cambrian ages.

ORIGIN OF THE MISSOURI KAOLIN.

The granite and porphyry areas of the southeastern part of the state which occur surrounded by the limestones carrying the kaolin do not furnish any workable kaolin deposits, as the clay resulting from their decay has thus far been found to be too impure with iron to answer for china-ware. This is a remarkable and quite unusual phenomenon for so extensive a district where both feldspathic igneous (plutonic) rocks and sedimentary limestones occur, to have large deposits of kaolin derived from the limestones, and none from the plutonic rocks. Yet the evidence is conclusive that the Missouri kaolin deposits thus far opened have been derived from the decay and solution of limestones which have left behind, as the insoluble impurities, beds of clay and large bodies of chert fragments as mere remnants of their former great mass. A characteristic feature of the Ozark uplift, or the elevated area which makes up nearly the whole of the southern half of the state, is the heavy beds of loose chert that more or less completely cover the region. This mantle of chert fragments is seldom absent when the underlying formation is limestone, and the limestones make up by far the greater portion of the Ozark region. As the chert mantle varies from a few inches to over one hundred feet in thickness, and as even in the most cherty limestones the chert concretions do not make up a large percentage of the whole, this chert wreckage indicates the removal of very extensive beds of limestone, which have quietly and invisibly disappeared through the solvent action of surface waters, while the insoluble impurities, as chert and clay, have quietly settled on top of the underlying, still unattacked beds. This residual mass is usually mainly chert, as these silicious concretions are the principle impurities in limestones, and the earthy and clayey matter is generally very subordinate in amount and is still farther reduced by its being more or less completely washed away by the mechanical action of the rains, if exposed on slopes. But occasionally the limestones are rich in earthy or clayey impurities, and the clay predominates over the chert. If the slope is so gentle that the clay does not wash away faster than it is set free a bed of clay results, which if derived from a limestone that is free from iron will be a bed of kaolin. This is what occurs so extensively in southeastern Missouri where certain beds of the old Cambrian and Ordovician limestones were unusually rich in earthy impurities yet so exceptionally free from iron as to leave large beds of kaolin. If such earthy limestones were overlain by the usual chert-bearing type of limestones the chert in the latter is first set free in the slow planing action, by chemi-

-cal solution, and the cover of chert fragments protects and hides the underlying clay. This is the case in Bollinger county where the kaolin usually occurs under a more or less heavy mantle of chert, or mixed chert and clay. Madison county has similar heavy bodies of residual clay under mantles of chert, but having been derived from earthy limestones that were more or less impregnated with iron, the resulting clays are ferruginous, or yellow to brown in color, and therefore worthless for china-ware. Such is the origin and usual mode of occurrence of the Missouri kaolins.

Occasionally the residual clay has been washed into a choked sink-hole or closed basin, where there results an accumulation of the fire-clay as a sedimentary deposit. Often the depressions are completely filled by the local washings from the adjacent limestone. This is the origin of the ball and flint clay deposits. In this case only the fine clay is carried into the basin and it is free from the chert that is so largely intermixed through the "hill" or residual deposits.

In thus ascribing the origin of the Missouri china clay deposits to the insoluble fine residual matter left by the chemical removal of heavy limestone beds, it is with the intention of tracing their parentage to the latest traceable source. But as all limestones are secondary rocks, or derived from the disintegration of still older rocks and as the primary or first tangible rocks were all of the granitic or feldspathic type, the clay that came from the limestone was all derived from these original feldspathic rocks, which are the primary source of all kinds of clay.

THE SOUTHEASTERN KAOLIN DISTRICT.

The southeastern kaolin district is the most important in Missouri. It has the only producing mines, an abundance of deposits, and a high grade of clays. As the present output of the district does not exceed 1,000 tons a year, valued at $4,000.00, its financial importance is in the future. When the deposits are systematically worked and the product washed, it will not only greatly enhance the value but enable a very much larger amount to be utilized, and will enormously increase the demand. The district comprises a number of counties. From Cape Girardeau and Bollinger large shipments are made. In Perry, Ste. Genevieve and Madison counties workable deposits are known. In Iron, Reynolds, Wayne, Carter, Ripley, Oregon, Shannon, Texas, Howell and Ozark counties outcroppings have been discovered.

The accompanying sketch map of Bollinger and Cape Girardeau counties shows the productive pits (figure 8). South of the kaolin belt occur deposits of potters' clay, in Scott, Stoddard and Butler counties that are probably of Tertiary age, while north of the kaolin

belt are found the ball clays of Jefferson and Franklin counties and the flint fireclays of Franklin, Gasconade, Crawford, Phelps, Maries, Osage and other counties. Of the counties in the kaolin belt, Cape Girardeau and Bollinger are the only two in which energetic prospecting has been carried on, and these are the most favorably situated for cheap shipping, while the quality is superior in being more free from iron and less plentifully associated with chert than that found in the other counties. The Cape Girardeau deposits have not thus far proved

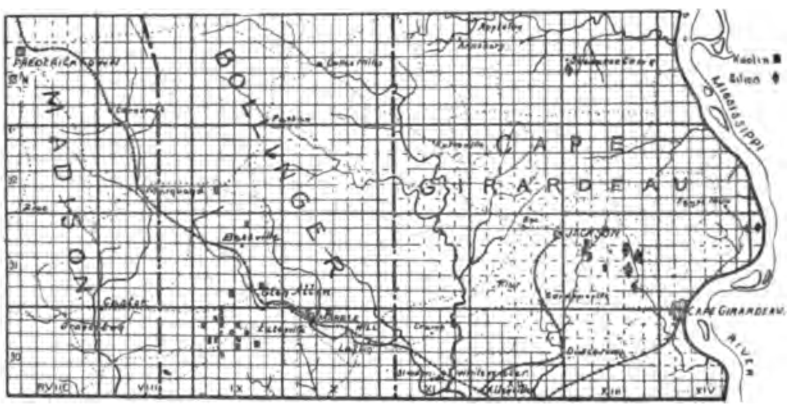


Figure 8. Sketch map of Southeastern Kaolin District.

very extensive, and while the quality is excellent, its future does not hold out as much encouragement as its neighbor on the west, Bollinger county, which latter is the most promising in the belt. The Cape Girardeau kaolin has been used by white-ware potteries, paper mills and for kalsomine, and has been shipped by river from Cape Girardeau and by rail from Jackson. From Glen Allen and Lutesville, in Bollinger county, though mainly from the former, large quantities of kaolin have been shipped to potteries at East Liverpool, Cincinnati, Indianapolis and Peoria, from pits that are from one to five miles from the railroad.

In Iron county, a small amount of work has been done in the neighborhood of the hamlets of Kaolin and Foote, supplying a small pottery that was once operated. No shipments have as yet been made from the other counties, partly because of inaccessibility, partly from the excessive admixture with sand and chert, but mainly on account of the excessive expense of shipping to the eastern markets.

The development of the kaolin belt has also been greatly retarded by the lack of capital and knowledge on the part of the owners of the kaolin pits, especially in not knowing how to sort the kaolin for the pottery trade, and this want of appreciation of the demands of the pot-

ter has heavily handicapped shipments from Glen Allen. It is necessary not only to carefully sort out the pink or iron-stained clay and the flinty clay, but also to grade according to the fineness of the grit or sand in the clay, as it is very essential to have a uniform and reliable, as well as a pure, kaolin, and the Glen Allen shipments have therefore fallen into disfavor among potters because of carelessness in sorting. The entire district has suffered from the lack of a washer, which would secure uniformity as well as purity. Until very recently there were none in this part of the state. Another serious drawback has been the careless system of mining, by which a heavy loss has occurred by not timbering the pits. This has resulted in as great a loss as seventy-five per cent of the clay, which could be largely, if not entirely prevented under a systematic method of mining, if carried out by experienced persons. The system of mining usually adopted consists in sinking a pit or shaft 4 to 5 feet in diameter to the kaolin, which may be from 5 to 100 feet deep, by a hand windlass. On reaching the marketable kaolin, the shaft is widened to 8 or 10 feet, and small drifts that are usually 3 by 6 feet are driven out through the kaolin bed. A small trench is dug around the mouth of the pit to carry off the surface drainage, and a windsail is sometimes erected over the pit to aid in ventilation; but the shaft is not timbered, the drifts are not supported, and reliance is placed on large pillars that are left to carry the overlying ground. The pits consequently cave in during wet weather, and are frequently abandoned during a very wet season, as a bailing bucket, worked by man or horse power, is the only way of removing the water. When the pit is over 20 feet deep, or the kaolin deposit is very extensive, a horse whim is usually erected, to replace the hand windlass. Steam engines and pumping machinery have not as yet been introduced, except in one or two instances. This crude system of mining is partly the result of inexperience in not knowing how to cheaply and safely work the treacherous kaolin beds, and partly to their rather limited size. When energetically and systematically worked in the future discretion will have to be exercised in not spending too much on the permanent plant, lest the small size of the deposit may not justify it.

Washing, or the separation of the sand and flint by a careful system of "floating" is needed at almost all of the kaolin deposits, and many can never be profitably worked without washing. A small washer was erected in 1893 at Glen Allen, but through mismanagement it was not a success in the hands of its original owners. The property is now under negotiation, which is likely to put it in the hands of experienced persons with ample means. The kaolin in the western

counties of this belt are in special need of washers before most of it can be successfully marketed.

Poor roads are another drawback that greatly hampers the development of the kaolin beds, and usually prevents deposits from being worked that are more than five miles from the railroad. The hauling, in consequence, costs from 50 cents to $2.00 a ton, according to the condition of the roads and distance, as it is done with light teams in farm wagons. In shipping, the kaolin has to stand a local freight rate to St. Louis, or the distributing point, of from $1.00 to $3.00 a ton, as the distance is from 130 to 250 miles, and a further charge eastward to the potteries of $1.50 to $4.00, making a total freight charge of $2.50, under the most favorable circumstances, to $7.00 a ton, usually over $5.00. As the kaolin brings from $8.00 to $12.00 a ton at the pottery, this does not leave a large margin for mining, royalties and profit, when the heavy waste is considered in sorting out the stained and sandy clay.

When a local market is secured by the establishment of potteries in or about St. Louis, and ample capital is employed to more economically mine and secure a very much more reliable product by washing, many deposits may be worked that are now out of the market, and it will stimulate prospecting over areas in which thus far there has been no inducement to look for kaolin. Improved haulage, by the employment of broad tires and heavy teams, will further aid in bringing outlying deposits into the market, especially if the roads are improved. Under the inducements of greatly reduced freights, a much less wasteful system of mining, with cheaper methods of hauling, and the ability to ship a uniform product by means of washing, an impetus will be given that at present cannot be predicted, while a development will result from the prospecting that will be thereby stimulated that will greatly enlarge the producing capacity of this district and very much widen the present area of workable deposits. The deposits and prospects that are herewith described do not by any means represent the possibilities of this district.

CAPE GIRARDEAU COUNTY.

Jackson Kaolin Beds. Cape Girardeau county produces a very pure white kaolin in the neighborhood of Jackson, that has been extensively shipped by rail, and by boat from the Cape Girardeau landing. An extremely silicious kaolin that frequently becomes almost pure silica and which is known to the trade as "silica" is also found in several places between Jackson and the river. The Jackson kaolin is very popular for kalsomine paints, for weighting and finishing paper

stock and for white ware. The kaolin appears to have been derived from the white, crystalline limestone that is found in heavy beds between Cape Girardeau and Jackson and which has been designated by Shumard as the "Receptaculites" limestone. This seemingly very pure limestone is comparatively free from iron, and the insoluble matter left by its chemical dissolution is in most cases either the previously mentioned excellent variety of kaolin, or the soft white silica.

The shipments made have been extensive during the past 20 years. They are rapidly diminishing on account of the exhaustion of the known deposits and prospecting thus far is not developing any large new ones. Since the first working of these deposits in 1874, there has been a total shipment of 12,000 to 13,000 tons, according to Mr. Ferdinand Brown, who gives the following information:

Production of Kaolin in Cape Girardeau County.

	Tons.
English pits	11,000
Brown pits	1,000
Moore pits	100
Niedringhaus pit (estimated)	100
Miscellaneous sources (estimated)	100
Total, since 1874	12,300

The kaolin usually sells for about $4.00 at the mine, and for about $12.00 at the pottery. The owner of the most extensive series of pits estimates that over one-half of the clay is left underground. The clay is easily sorted from the iron-stained impurities and is usually not contaminated with either sand or chert. It is a soft, pure white, gritless clay, that is usually quite plastic and very easy to work.

Cape Girardeau Pottery. Cape Girardeau has the honor of having started a white-ware pottery in 1882, though it did not prove a financial success. From Mr. Henry L. Henze, president of the company, the following information was obtained. In 1881 a young potter, James Post, successfully made Rockingham ware in a small kiln from the Cape Girardeau clays. He induced local capital to form a company, with $20,000.00, with which was built a small two-kiln pottery. The feldspar was shipped in from the east, while the flint, kaolin and sagger clay was obtained in Cape Girardeau county. A "C. C." ware was produced, but through bad management and incompetency, most of it was unsalable, and after two years of varied experience the concern stopped with a debt of $20,000. It was leased by a co-operative pottery association, made up of twelve journeymen potters, who were all experienced workmen, but with no capital. They made a success of the product, which was a heavy grade of "C. C." ware, but from internal

dissension and a lack of working capital, it again proved a financial failure. No further attempts were made to run the pottery, and the plant was finally sold to a Mr. Matteson, who tore down the kilns and converted it into a grinding mill for which purpose it has been used since. Big Muddy coal was used for firing the kilns, which proved satisfactory, and the ware was shipped by river mostly to the St. Louis market. The unfortunate experience has disgusted Cape Girardeau capitalists with the pottery business, which probably would have been a moderate success under good management. It was an unfortunate place to start a pottery on account of its distance from skilled labor, and great difficulty was experienced in getting competent potters, while there was no local market and none of the interested capitalists knew anything about the pottery business. Under such circumstances it is not surprising that the experiment proved a failure, as the only advantage enjoyed was proximity to clays, which can be shipped much more cheaply than the finished ware. But this failure has been freely used by a non-discriminating public as indicating the impossibility of successfully carrying on the pottery business in Missouri.

English Clay Pits. About two miles from Jackson, and eight miles from Cape Girardeau, on the excellent turnpike connecting the two places, is a series of pits along the south side of the road, which have produced the bulk of the kaolin shipped out of this county. Extending for over a half a mile, and within 20 to 300 feet of the road, are six groups of shafts, with a gap of about 500 feet between each group. They occur chiefly in the S. ½ of Sec. 7 (Tp. 31 N., R. XIII E.)

These pits were first opened in 1874, when the Cincinnati Kaolin company leased the eastern end of the property. Subsequently the pits were leased by Dovey Bros. of St. Louis, who are said to have taken out about 5,000 tons during a ten-year lease, the output being used for paint. On the expiration of the Dovey lease, in 1887, Mr. English operated the pits for several months, and shipped about 500 tons. Later Mr. Matteson of Cape Girardeau, leased the pits and shipped about 2,000 tons. Still later a Mr. Hoffman of St. Louis, shipped 500 tons, and a Mr. Wait, of Michigan, about 3,000 tons. For the past two years little has been done, beyond a limited amount of prospecting, and the total production to date from these pits is about 11,000 tons. Most of this clay has been hauled to Cape Girardeau, at $1.80 a ton for hauling. The English kaolin has sold from $4.50 to $12.00 a ton delivered on car or boat, according to quality, usually for about $6.00.

For convenience the pits have been classed into groups, as indicated farther on. The shafts of group *A* are 45 to 65 feet deep,

and are all sunk in a small ravine. A small pond now occupies the site of the principal pit of the group and a loess-covered hill rises on the south side to a hight of 35 or 40 feet. This hill shows a soft white to yellow friable sandstone, which is capped by a fine-grained, gray, compact limestone that is tilted 45 degrees to the southeast, or in the direction of the hill. Some pink and white clay is intermixed with the sandstone, and red and white clays crop out along the side of the ravine beyond the sandstone exposure. The marked continuity in the direction of the pits, the association with the pure limestone of the district, and the independence of the present topography, suggest that the kaolin occupies a series of old sink-holes in the limestone. In one of the shafts peat was struck, which is still to be seen on the dump and which was used to some extent under the boiler that ran the steam pump at the mine. The peat is said to have been 20 feet thick, and under it to have white kaolin. It was reputed to be dipping strongly, or was cut on edge. It is a well altered, compact, brown to black mass, and had nearly attained the condition of lignite.

Shaft *B*, which lies about 500 feet from group *A*, reached white clay within 5 feet of the surface, but it was more or less mixed with sand, and before a depth of 30 feet was attained, some gravel made its appearance and it was abandoned. One of the shafts of group *C* is said to be 108 feet in depth, and another only 50 feet. Of the six shafts, in this group, four met with the clay and two did not. In the shaft in which the white clay comes to within 6 feet of the surface, it is capped by one-half to one foot of mixed limonite, chert and sandstone, overlaid by 2 to 3 feet of angular chert in a tough joint clay, under 2 to 3 feet of top soil. The capping of the clay by the limonite or iron ore ("iron horse") is quite characteristic of these deposits. Most of these shafts have been worked by a horse whim. Prospecting this area with an augur was found to give unsatisfactory results, as the color was generally found to be less favorable than indicated by the borings. On account of the gravel and iron ore that generally occurs over the kaolin, it is necessary to sink a pit through them before boring with the augur, which usually shows bodies of red and yellow clay resting on the kaolin. While the pits and borings show great bodies of clay along this run or series of kaolins, the greater portion is more or less discolored pink, red or yellow by iron, and the white kaolin makes up only a small proportion of the whole. Careful selection is necessary to maintain a pure grade, as occasionally the white clay is found mixed with sand and chert.

Brown Pit. On the north side of the Jackson and Cape Girardeau turnpike, and opposite group *D* of the English clay pits are the

Brown clay pits. Four small shafts have been sunk, within 25 to 40 feet of one another, that are from 15 to 25 feet deep. The pits are on the crest of a hill, and the clay comes within 10 feet of the surface. The summit is capped by loess, but no iron or river gravel is found. As in the English pits, the white clay lies in pockets in great bodies of impure iron-stained clay. The shafts are single compartments and from 4 by 4 feet to 6 by 6 feet in size. The drifts, 4 feet wide by 7 feet high, are driven out from the foot of the shafts, through the pure kaolin, and are supported by three-quarter sets with top and side lagging. The clay is soft and readilly worked by pick and shovel, and the mining, timbering and hauling to Jackson, one and one-half miles distant, is contracted for at $4.00 a ton. The farm, which consists of 135 acres, is leased by the Dovey brothers of St. Louis, who have a ten-year lease, and pay a royalty of 50 cents a ton. Mepham and Klein have thus far taken all the clay for paint, kalsomine and paper stock, and the total production, since the pits were opened in 1877, has amounted to about 600 tons. The pits are now exhaused, and limited prospecting has not yet discovered any new bodies of kaolin although there are favorable indications of other deposits near by.

Moro Pit. About eight miles west of Cape Girardeau, and one-fourth mile south of the Jackson turnpike is a small pit that was opened in 1885 on the land of Gus Moro, by Mr. Matteson of Cape Girardeau. Only about 100 tons of kaolin were extracted.

Neideringhaus Pit. About seven miles west of Cape Girardeau and one-half mile south of the Jackson turnpike on the old Lyell farm, is a small pit that has been operated in the interest of the St. Louis Stamping Company of the Neideringhaus brothers. It lies in a small ravine, at the base of a loess-covered hill that rises from 30 to 60 feet higher, and at a point at which white clay crops out. The clay is white to blue in color, very fine-grained, very slightly micaceous, gritless and very plastic. Some of it was yellow stained and brown, but most of it was quite free from such contamination by iron. About 40 to 60 barrels of 400 pounds each are shipped a year to St. Louis, where it is used in making enamels for "granite" iron ware.

Collins Bank. About three miles west of Cape Girardeau, and about from one-half to three-fourths of a mile south of the Jackson turnpike, on the Collins farm is an out-cropping of white clay at the spring at the base of a limestone hill within 200 feet of the house. White clay crops out over several square yards, that is very fine-grained, very plastic, and apparently of excellent quality. It seems to be at least 4 feet thick, and is probably thicker. The limestone is the typical white, sub-crystalline "Receptaculites," that is so characteristic

of this region and is very rich in crinoid stems and chert. No work has been done to develop this clay, and its quality and magnitude are unknown, though there is but little doubt that the clay occupies an old basin or sink-hole in the limestone.

Claproth Bank. Three miles west of Cape Girardeau, and one-half mile south of the Jackson turnpike, on the Claproth farm, is a body of clay that was formerly worked for saggers by the Cape Girardeau pottery. Only a limited amount was taken out and shipped to the pottery, probably less than 25 tons. There is said to be 2 to 3 feet of white clay, which is overlain by more or less intermixed red clay. It occurs along a small dry branch in an easy rolling country.

Steinbern Pit. Three miles north of Cape Girardeau and two miles west of the Mississippi river on Juden creek, a bank of china clay was opened in 1892, from which 15 tons were shipped that year. According to Gluck there is a pocket of white potters' clay that is very much intermixed with yellow to greenish iron-stained clay and limestone bowlders.

Silica Deposits. There occurs in Cape Girardeau county some interesting deposits of nearly pure silica in the form of soft white pulverulent masses, that are popularly known as "silicia." These deposits are similar in origin and mode of occurrence as the kaolins or clays, in consisting of the insoluble silica that has been left behind in the chemical dissolution of the limestones. They differ radically from the usual type of such residual matter as chert and flint in having been sufficiently contaminated by lime as to break into fine, soft, pulverulent material on the leaching out of this calcareous part by weathering. As all the chert was not contaminated with lime, fragments are found intermixed with this soft silica, as well as more or less aluminous or clayey matter. While apparently having no connection with the clay industry, these deposits of silica have been freely taken advantage of as a substitute for flint, in the manufacture of whiteware pottery. They are therefore described here as they are destined to become important, should local potteries be established, and this material is now being largely used as a wood filler for paints.

Brooks Silica Pit. About five miles north of Cape Girardeau and one-half mile west of the Mississippi river is a pit of silica on the Brooks land. It was opened in 1891, since which time it has been worked by Mepham and Co., of St. Louis, who pay a royalty of 6 cents a barrel. It is hauled to the river and shipped by boat to St. Louis. The deposit occurs at the foot of a hill on a branch of Big Flora creek, and about 250 barrels are shipped annually.

A sample from this deposit that was collected gave the following results: Color white, with occasional yellow to brown-iron stains. Texture coarsely laminated, very soft (1.0), rather fine-grained and uniform. Taste extremly lean. Slacking uneven, most of it rapidly and completely. Pyrite was not noticeable. When ground to 20-mesh and mixed with 29.0 per cent of water, it made a soft, very lean paste that shrunk 2.4 per cent on drying, and 6.3 per cent when vitrified, giving a total shrinkage of 8.7 per cent. The dried mud had an average tensile strength of 23, and a maximum strength of 26 pounds for each square inch. Incipient vitrification occurred at 2,300° F, complete at 2,600°, viscous above 2,700°. It burned to a white, compact tough body when vitrified, but from its extreme leanness was weak unless vitrified. It rapidly dried, but checked with rapid heating. Specific gravity was 2.02.

An analysis give the following results:

	Per cent.
Silica	91.05
Alumina	5.01
Combined water	2.74
Iron sesquioxide	0.69
Lime	0.24
Magnesia	0.22
Alkalies	0.12
Total	100.07

Juden Deposit. On the Juden farm, 3 miles north of Cape Girardeau, Gluck notes the occurrence of a pocket of silica, at the base of a hill on Juden creek. As far as the meager developments show, it is considerably mixed with flint.

Stevens Pit. About five miles north of Cape Girardeau, and one mile west of the Mississippi river is a silica pit on the Stevens land. It was opened about 25 years ago and operated in its early history by Mepham and Co., who have shipped as much as 1,000 barrels a year, of about 500 pounds each. The deposit is reached by one shaft about 45 feet in depth, and by another of about 25 feet. It lies at the foot of a hill on a branch of Juden creek. The deposit is worked by the room and pillar method, in which the rooms are carried 4 feet wide, by 6 feet high, leaving pillars 4 feet wide. This is an exceptionally large and pure deposit, though it is occasionally injured by streaks of chert. The material has been mainly used for paint and as wood filler.

Williams Silica Bank. Five miles northwest of Cape Girardeau, on the Williams farm is a large deposit of silica. It was opened about 10 years ago, and has produced about 1,200 tons yearly for the past 5 years. The output is sold for $3.50 a ton delivered to Matteson & Co., of Cape Girardeau, to which point it is hauled by wagons to be ground

into paint. The deposit occurs on rather a high hill and is over 30 feet deep, with the probability of exceeding 50 feet. It has been drifted into for a distance of over 50 feet, while a ravine to the east of the pit seems to indicate that it is at least 1,000 feet in length. It is worked by the room and pillar system by driving in from the hillside. About 30 per cent of the silica is left in the mine. It is readily dug with pick and shovel. It is overlain by 2 to 7 feet of soil, flint and clay which is not stripped off.

Charles Williams Silica Bank. Six miles northwest of Cape Girardeau and one mile north of the Jackson turnpike is a bank of silica on the Charles Williams place. It occurs at the base of a hill on a branch of Cap la Croix creek, where a face is exposed for a length of 200 feet and to a height of 60 feet. It consists of chert partly soft and pulverulent or decomposed, partly altered and partly hard and unaltered chert. The more or less altered fragmental matter predominates over the completely altered material. Occasional seams of gray plastic clay occur between the chert fragments that are similar in character to the china clay deposits at Jackson. Limestone, in thin-bedded horizontal layers, crops out along the creek bank immediately east and west of this deposit, on about the same horizon, thus showing that it is only a pocket in the limestone. A drift 10 by 12 feet has been run for a distance of 25 feet into the deposit, but on account of the excessive amount of fragmental matter, only a small amount has been shipped, and the bank has not been operated for several years.

Other deposits of silica occur 10 miles northeast of Jackson, at Shawneetown, and at Wittenberg, on the Mississippi river, in Perry county, at Grand Tower and Anna, Illinois, which are close by, on the Illinois side of the river. They also occur at Chalk Hill, on the Mississippi River and Bonne Terre railroad, one mile north of Doe Run, in St. Francois county.

BOLLINGER COUNTY.

Glen Allen. This county is the richest in the state in the number and thickness of its kaolin deposits, which are mainly located in the neighborhood of Glen Allen. The following historical information was furnished by Judge David Stevens. The first kaolin mined in Bollinger county was taken out about 1857, by a Mr. Dallas of Cincinnati, Ohio, where he had a pottery that is now known as the Brockman works. For 5 years clay was shipped from here to the Ohio pottery. The Cushman lands were originally purchased and worked for the iron ores they contained, but inspired by Mr. Dallas, prospecting was begun for clay

and with such success that considerable kaolin was produced. About 1872 the people of Glen Allen began prospecting, and opened about 50 pits during the ensuing two years. The kaolin was bought by Snyder and Stevens, at $2.00 to $5 00 a ton and shipped to the potteries at Cincinnati, East Liverpool, and other eastern markets, the total product being about 400 tons a year. About 1874 the mines of Snyder and Stevens were leased by Taylor Bissell, of St. Louis, who attempted to operate them on a large scale. After taking out 360 tons he abandoned them the following year, as the market for Bollinger county clays had been severly injured by the kaolin being too greatly contaminated with sand and gravel. Heavy shipments were made from Glen Allen in 1884, from which 500 tons per annum were sent out. Since that time the production has diminished on account of the growing disfavor arising from careless sorting. About 300 tons are now shipped each year, which is estimated to represent one-fourth to one-third of the total quantity actually mined. From a very ripe experience as a miner and shipper, he states that a three-foot thick seam is as thin as can be profitably worked.

The kaolin deposits in this district are evidently the insoluble residues from very extensive beds of former impure argillaceous and silicious limestone. They are therefore in place, or occupy about the site of the former overlying limestones from which they have been derived. Some washing and therefore sorting has undoubtedly taken place, but the developments do not thus far indicate that this has been extensive or of much importance. Some of the deposits are found at or near the tops of some of the highest hills and ridges as well as on the flanks, and in the intervening valleys. In consequence of the kaolinite not having been washed or sorted to any appreciable extent the deposits vary greatly in character and are greatly wanting in uniformity. They are usually capped by chert fragments or flint gravel on the surface, which changes into a mixture of chert, sand, and kaolin that at greater depths merges into more or less pure bodies of the latter that may be from 5 to 25 feet in thickness, and which rest on a mixture of chert, sand, and kaolin. The salient point in the kaolin beds is the greater or less contamination of an otherwise good quality of kaolin by an intercalated mass of sand and chert fragments. This has caused a heavy wastage from the lack of facilities for washing and thereby removing the coarse material that prevents the use of the kaolin until eliminated. The deposits will yield a very much larger percentage of kaolin, that will be of much greater uniformity and reliability, when the district is favored with ample washing facilities. One small washer was erected for this purpose in 1893, but the district

could support several, as no kaolin should be shipped without washing. Few if any of the deposits can be relied upon to furnish any large quantities of kaolin of uniform grade that is not injured by coarse admixtures of sand and chert. The reputation of the place has been greatly injured, and the shipments heavily curtailed because of the sand and expensive experience of potters from this trouble. The outlay for such a washer is not very great as it can be built for $5,000. to $15,000. according to the design and capacity; but local capital has not appreciated the importance and the necessity of making this outlay, and it remained for outside capital (Chicago) to erect the first washer.

On account of the very poor roads in this county and the pits being from one to five miles from the railroad, the hauling is usually confined to about six months of the year, as the roads are too heavy at other times. Storage sheds have been built at the railroad station, at Glen Allen, that are filled during the dry season, and which enable shipments to be maintained throughout the year. These sheds have been erected by dealers or middle men, who usually buy the clay from the miners and ship direct to the potters. These middle men pay from $2.00 to $4 00 a gross ton and sell to the potters for $4.00 to $7.00. The general character of the kaolin deposits is remarkably uniform and a description of one quite fairly represents the character of all.

Stevens Pits. Two miles west of Glen Allen (Tp. 30 N., R. IX E., Sec. 4, NE. qr.) is a series of clay pits that have been extensively worked on a royalty of 10 to 25 cents a ton. Shaft *A*, opened in 1892, is 25 feet deep, and gives the following section:

	Feet.
5. Soil and gravel	2
4. Soil and kaolin, mixed	3 to 4
3. Kaolin, gravel and sand, mixed	9
2. Kaolin, pure	1 to 4
1. Kaolin, gravel and sand, mixed	10

The gravel or chert is usually angular, white to brown in color, and is accompanied by fragments of white sandstone and sand. Most of the chert or flint is hard and compact and from one-fourth to three inches in size; but some of the fragments are soft and porous and show evidences of the leaching of lime and its incipient dissolution into white sand or "tripoli." Joint planes that run through the kaolin, or the mixed kaolin, are sometimes stained yellow to red with iron, while the kaolin is frequently pink in color. Sometimes this pink color appears to be organic in origin for it burns out, leaving the kaolin colorless, while in other instances the clay becomes brown after burning. The shaft is about 6 feet in diameter and is not timbered. A trench about 18 inches in depth is cut around the top to carry away the surface

drainage and the pit is perfectly dry. Drifts 3 feet wide and from 3 to 8 feet high are run out through the kaolin with but little if any timbering, and about one-half of the kaolin is left untouched as pillars to support the roof. Only the clean kaolin is worked, the mixed material being left. The pick and shovel are used exclusively. One man works in the drift while another mans the windlass and attends to the surface work. About two tons a day are mined from a fair sized body of clay, and as high as 4 tons a shift have been won. The kaolin is stored in sheds or roofed log cribs to protect it from the weather and permit its drying out.

Shaft *B* is 25 feet deep but shows no pure clay. It consists of a mixture of sand, gravel and kaolin from top to bottom. These two shafts are leased on a royalty of 10 cents a ton shipped.

Shaft *C* is 16 feet deep, and has thus far only shown mixed kaolin sand, and gravel.

Shaft *D* is a large producer of kaolin, while other shafts 20 to 40 feet west and 25 feet south do not reach clean kaolin.

Shaft *E* shows 15 to 18 feet of mixed kaolin, gravel and sand, and then changes to 10 feet of yellow sand. It contains one clean seam of kaolin that is 8 to 10 feet thick which strongly dips, but it splits up into two thin seams and cannot therefore be profitably worked.

Slemmer Pit. This is about 3 miles west of Glen Allen (Tp. 30 N., R. IX. E., Sec. 5, SE. qr.) on the crest of a high hill. There are several pits that have been sunk on about an acre that are from 60 to 75 feet deep, and which show several lenses or bodies of pure kaolin of variable thickness, between bodies of mixed kaolin and gravel. One of the fragments consisted of a bowlder of black flint 4 feet in diameter. The pure kaolin is reached at a depth of 14 to 20 feet from the surface and the best is at the bottom, where it is harder and less plastic, but more free from iron and pink stainings.

Numerous other kaolin pits exist in the Glen Allen district. Their locations given by Mr. J. B. Beilley, county surveyor, are as follows, all of which are in township 30 north, range nine east:

Snyder pit	NE. qr., Sec. 4.
Sharp pit	SE. ¼ of the SW. qr., Sec. 4.
Somers pit	NE. ¼ of the NE. qr., Sec. 7.
Einwechter pit	NE ¼ of the SE. qr., Sec. 9.
Crawford pit	SW. ¼ of the NW. qr., Sec. 9.
Reilly pit	NW. ¼ of the NW. qr., Sec. 10.
McManus pit	NE. ¼ of the SE. qr., Sec. 10.
Stenum pit	NW. ¼ of the SW. qr., Sec. 15.
Dobschutz pit	NE. ¼ of the NW. qr., Sec. 15.
Waldo pit	SW ¼ of the SE. qr., Sec. 15.
Cushman (St. Louis)	NW. qr., Sec. 17.
Low pit	NE. ¼ of the NW. qr. Sec. 17 .
Lyley pit	NE. ¼ of the NW. qr., Sec. 24.

Glen Allen Washer. Under the name of the Glen Allen Mining Co., Messrs. S. L. Jaques and Geo. L. Stuart of Chicago, formed a stock company and built a small washer one-half mile north of the Glen Allen station. The plant consists of two washing tanks that are about 5 by 5 feet in size ; an agitator or plunger, about 4 by 5 feet ; a force pump, and a filter press of one and one-fourth tons capacity. It is equipped with a small boiler and engine, and is conveniently housed in a frame building. After operating about two months, during which time about 4 tons of kaolin a day were treated, the company failed, and is still (1895) in the hands of its creditors, though with fair prospects of being purchased and started up by others. The washing loss was said to be six to seven per cent. The washed clay was offered at $6.00 to $7.00 a ton, while unwashed clay could be bought for $2.00 to $5.00. The plant was operated by 2 to 4 men, and the washing expenses are said to have not exceeded $1.55 a ton. It is very conveniently located on the bank of Crooked creek and is connected by a switch from the Belmont branch of the St. Louis, Iron Mountain and Southern railroad. The creek furnishes an abundance of clear water during all seasons of the year.

Bessville. About four miles northeast of Bessville is a kaolin pit 45 feet deep from which one car was shipped in 1892 by Jacob Berry, of Glen Allen. It has 7 feet of a good grade of kaolin, but the road to the railway is not very good. Another pit that shipped kaolin to the St. Louis pottery, in 1862, lies about 5 miles east of Bessville. It produces a very fine, white kaolin.

Lutesville. On the Lutz land (Tp. 30 N., R. IX E., Sec. 14) the following section occurs:

	Feet.
4. Soil	4
3. Clay, colored	8
2. Chert	2
1. Kaolin	10

Four cars were shipped in 1882 by a Mr. Waldo, since which time nothing has been done. Immediately north of this tract on the McClinick place, are several shafts that were sunk about 1872 but were not operated again until 1886, when they were reopened and about 20 car loads shipped. On the David Lutz land are other kaolin pits. In a ravine by the roadside (Tp. 30 N., R. X E., Sec. 5) there are 5 feet of kaolin under 5 feet of soil. On the Morgan land (Tp. 30 N., R. X E., Sec. 4, NE. qr.) a pit is said to have been dug 7 feet deep, producing good kaolin.

IRON COUNTY.

Kaolin. At the old town of Kaolin, about 12 miles west of Iron Mountain station on the St. Louis, Iron Mountain and Southern railroad, are some pits and prospects which furnished kaolin to the old Pool pottery. None of these pits have been worked recently as the distance is too far from the railroad to admit of profitable operation. On the Middleton farm there is an exposure of mixed kaolin and flint, at the base of a hill over 100 feet high, that shows 20 feet above the creek level. The kaolin is soft, very fine-grained, lean and of excellent quality, though occasionally having yellow spots and streaks. The old workings were on the east side of the Ottery fork of Black river (Tp. 35 N., R. I E., Sec. 36).

Montana. Near this place, which is six miles west of Kaolin and eighteen miles west of Iron Mountain, there are several old kaolin pits. Kaolin is reported as occurring in the center of section 32 (Tp. 35 N., R. I E.); also in the same township, on the Barger land on the Salem road in the northwest quarter of section 33 and in the northeast quarter of the same section, at a depth of 22 feet.

Foote. This is the site of the first white-ware pottery in Missouri, and one of the pioneers of the Mississippi valley. It was located in the east part of lot 1, (Tp. 34 N., R. I W., Sec. 1, NW. qr.), and was known as the Pool pottery. It was operated by potters from England. It was a small concern which has long since been obliterated, and the clays were derived from the immediate neighborhood, as well as from Montana post-office. The ware was hauled to the St. Louis, Iron Mountain and Southern railroad, 20 miles east, for shipment to market. In the eastern part of lot 3 there is reported to be 8 feet of mixed kaolin and flint at a depth of less than 10 feet. Kaolin also occurs in the northern part of lot 2 in the northwest quarter of section 2. At the Burt pit (Tp. 34 N., R. I W., Sec. 2, NE. qr.) there are 5 feet of kaolin at a depth of 10 feet, and the kaolin is associated with a soft specular iron ore. In the northeast fourth of the northwest quarter of section 11 there is an outcropping of sand and kaolin which indicates a deposit of pure kaolin.

Des Arc. A thin bed of very sandy, mixed white and yellow kaolin crops out for about 300 feet along the bed and bank of Goose creek, about one-half mile southeast of the railroad station. The clay is intermixed with fragments of sandstone and quartz, and could only be utilized by washing, which would cause great loss. It is protected by an outcropping ledge of light brown, sub-crystalline, magnesian limestone. It is on the edge of a meadow, and while it is too impure

to be used, it indicates the probable presence of kaolin deposits that may be sufficiently large and pure to be of commercial value.

WAYNE COUNTY.

Brunot. On the Chilton land, one mile southeast of the town, a seam of kaolin was encountered at a depth of 25 feet, that was overlain and underlain by red clay. The kaolin was from one-half to two and one-half inches thick and of a fine, soft, plastic white character. The excavation is on top of a gentle knoll, in a wide valley. About 400 feet north, kaolin is said to have been struck within 3 feet of the surface.

MADISON COUNTY,

Fredericktown. On the Wulford land (Tp. 36 N., R. IV E., Sec. 2, SE. qr.) a pit was opened in 1887 that showed seams of kaolin intermixed with red and yellow clays. The kaolin is soft, very fine-grained, pure white when sorted, and very lean. It is also occasionally intermixed with coarse sand but this is removed by sorting. On the Parsons land (Tp. 32 N., R. IV E., Sec. 11, NW qr.), on Matthews mountain, and on a branch of Cedar creek kaolin has been found. It is soft, very fine-grained, lean, and white, but is contaminated by streaks of colored clay, and by fragments of sandstone, quartz and sand. In the southwest corner of Madison, 6½ miles northeast of Brunot, near the Ironton and Fredericktown road, on Leather creek, white to yellow kaolin mixed with sand is exposed on a small dry branch. It is intermixed with chert, and is exposed for about 100 feet in the bank of the branch; it is from 1 to 3 feet thick, overlain by 1 to 2 feet of soil. While of no commercial value as it is exposed in the bank, it is useful as indicating the probable presence of valuable deposits. Kaolin was also found on the Green land (Tp. 32 N., R. VII E., Sec. 4, SW. qr.) at a depth of 6 to 12 feet.

PERRY COUNTY.

Silver Lake. White kaolin occurs on the Prevalley land (Tp. 34 N., R. IX E., Sec. 10), about one and one-half miles east of Silver Lake. It crops out in a small dry branch and is surrounded by a light gray, compact limestone. A pit that was sunk 100 feet south of this outcrop, after passing through 5 feet of yellow soil, penetrated a bed of white clay or kaolin that appeared to be clean and solid. It occurs on a hillside in a gently rolling country. Another pit was sunk 100 feet south of the above which also reached kaolin. About 5 miles south of Silver Lake on the Dolls place (Tp. 34 N., R. X E., Sec. 20,

SW. qr.) kaolin was met with in digging a well 70 feet deep. It was overlain by red and yellow clay and was 1 to 3 feet in thickness. It is very siliceous and varies in color from slightly pink to white. White kaolin is also said to occur on the Hunt farm, 4 miles southwest of Silver Lake. It is two feet in thickness and was found in prospecting for lead.

STE. GENEVIEVE COUNTY.

Jonca. Kaolin is said to occur near Jonca, on the Triplett farm (Tp. 36 N., R. VII E., Sec. 9, NW. qr.) in thin seams from 6 to 18 inches in thickness, and near the surface. No work has yet been done on it. Samples examined consist of a white, soft, heavy kaolin of fair quality. Other specimens forwarded by Mr. Douze showed a sandy white clay that is said to have come from a body 5 feet thick.

Coffman. About one-half mile east of Coffman a white clay occurs on the Aubuchon farm, but its extent is not yet determined.

Avon. On the Count land, 3 miles east of Avon, a light gray, fine-grained, fat clay occurs that comes from the surface near a small branch. On the Bidwell place, four and one-half miles southeast of Avon is also another deposit of white clay; and about 5 miles southeast of the same town on a wood road one-half mile west of Coldwater creek, a light gray plastic clay crops out in a ravine. It is overlain by 2 feet of red clay.

CARTER COUNTY.

At Chilton, on the land of the Missouri Lead and Mining Co., is a so-called "chalk bank." A sample of this kaolin gave the following results: Color mostly white (dry), with some pink to purple, somewhat stained brown by iron. Texture massive, very soft (1.0), very fine-grained, and uniform. Taste slightly of alum, and rather fat. Slacks rapidly and completely into fine granules one-fiftieth to one-twentieth of an inch in size. A washed sample when mixed with 18.0 per cent of water shrunk 5.8 per cent in drying, and 10.5 per cent when vitrified, giving a total shrinkage of 16.2 per cent. The air-dried mud had an average tensile strength of 20, and a maximum strength of 23 pounds to the square inch. Incipient vitrification occurred at 2,300° F., complete at 2,500°, viscous at 2,600°. It burned to a pink to gray, compact, rather tough body when vitrified, and rapidly dried, but checked and cracked badly when burned. This can probably be prevented by very slow heating.

A chemical analysis gave the following results:

	Per cent.
Silica	73.82
Alumina	18.16
Combined water	6.16
Iron sesquioxide	1.32
Lime	trace.
Magnesia	0 21
Alkalies	0.24
Total	99 91

RIPLEY COUNTY.

Doniphan. On the Keine land (Tp. 24 N., R. III E., Sec. 23, SE. qr.) a well was dug which gave the following section:

	Feet.
5. Soil	15
4. Kaolin	10
3. Clay, joint, and chert	10
2. Gravel, chert	3
1. Interval	7

On the Sanderson place (Tp. 22 N., R. III E., Sec. 17, NW. qr.) a well sunk to a depth of 90 feet penetrated mixtures of sand, gravel and clay; and in the lower part the clay appeared to be a white kaolin

Varner. On the Harper land, on the Varner and Doniphan road (Tp. 23 N., R. III E., Sec. 23, NW. qr.) the following section occurs:

	Feet.
4. Sand, chert and clay	40
3. Chert, gravel	1
2. Kaolin, white	17
1. Clay, yellow, sandy	2

A specimen from this apparently thick kaolin deposit showed that it was a soft, very fine-grained, white, lean kaolin, with occasional yellow stains. At the Henne place (Tp. 22 N., R. III E., Sec. 27, NW. qr.) 6 to 8 feet of kaolin are said to have been struck at a depth of about 50 feet, under joint clay, sand and chert. On the Jetmore land, 3 miles from Varner, white clay was found in a well, at a depth of 3 feet.

REYNOLDS COUNTY.

Centerville. About two and one-half miles northeast of Centerville, on the Pilot Knob road, near the crest of a high hill and near a cut in the road, a deposit of white, red and yellow clay is exposed. The white clay or kaolin is 1 to 6 feet in thickness, but is intermixed with flint and sandstone. It seems to be a fair quality of kaolin, if washed from the grit that it contains, and it suggests the presence of larger bodies of purer material.

Lesterville. About 3 miles east of Lesterville on the Brown land (Tp. 32 N., R. III E., Sec. 14) and about 200 yards south of the Lesterville and Sabula road, is an exposure or bank of white and bluish chert and white kaolin. A similar mixture of flint and kaolin occurs in a parallel hollow about one-half mile east of the above. While these outcrops are not valuable in themselves, they indicate purer beds in depth, or in the immediate neighborhood. On Paoli creek (Tp. 32 N., R. II E., Sec. 26) in Alcorn hollow, three-fourths of a mile east of Black river and about three miles southeast of Lesterville is an outcrop of mixed flint and white clay. This mixture shows for about 30 feet along the creek, and in it are pockets of nearly pure clay. It is a lean, silicious, plastic, nearly white to slightly yellowish kaolin, and it is popularly known as the "whitewash bank, from its use by the farmers for whitewashing.

OREGON COUNTY.

Thayer. On the Arnold land seven and one-half miles east of Thayer, and 300 yards north of the Arkansas line, a shaft has been sunk that discloses 6 feet of kaolin. A sample gave the following results: Color white, considerably stained pink to yellow and brown (dry), the stains penetrating the clays. Texture massive, very soft, fine-grained and uniform. Taste lean and finely gritty. Slacks rapidly and completely into flakes but mostly grains one-eightieth to one tenth of an inch in size. Pyrite was not noticeable; sand grains apparent. On washing the kaolin loses 13.0 per cent and becomes a pinkish brown color. When mixed with 23.0 per cent of water it formed a lean, soft paste that shrunk 3.2 per cent in drying, and 3.3 per cent when vitrified, giving a total shrinkage of 6.5 per cent. The air-dried mud had an average tensile strength of 13, and a maximum of 14 pounds to the square inch. Incipient vitrification occured at 2,300° F., complete at 2,600°, viscous above 2,700°. It burned to a gray, compact, rather strong vitrified body, and required to be very slowly heated to avoid cracking.

A chemical analysis give:

	Per cent.
Silica	81.18
Alumida	12.14
Combined water	4.52
Iron sesquioxide	1.88
Lime	0.16
Magnesia	0.14
Alkalies	0.18
Total	100.20

SHANNON COUNTY.

Winona. On the Questy land, two miles north of Winona on the Summerville and Winona road, several wells have been sunk in a valley on a branch of Pike creek. In a well that is 51 feet deep a mixture of flint and kaolin was struck at a depth of 3 feet. A sample taken from the dump gave the following results: Color partly white, but largely yellow with some pink (dry). Texture massive, very soft, very fine-grained and uniform. Taste fat and slightly gritty. Slacks rapidly and completely to fine grains one-fortieth to one-tenth of an inch in size. Pyrite is not noticeable; mica is present in small amounts. When ground to 20-mesh and mixed with 28.0 per cent of water it made a rather plastic paste that shrunk 9.4 per cent in drying and 9.4 per cent when vitrified, giving a total shrinkage of 18.8 per cent. The dried mud had an average tensile strength of 152 and a maximum of 201 pounds to the square inch. Incipient vitrification occured at 1,800° F., complete at 2,000°, viscous at 2,200°. It burned to a brown, compact, tough body when vitrified, and was rapidly dried and heated. Specific gravity 1.86.

A chemical analysis gave:

	Per cent.
Silica	56.74
Alumina	27.29
Combined water	6 20
Moisture	1.20
Iron sesquioxide	6.87
Lime	0.26
Magnesia	0 18
Alkalies	0 21
Total	99.95

A well 55 feet deep at the Edmonson mill (Tp. 26 N., R. III E., Sec. 9, NW. qr.) gave the following section:

		Feet.
6.	Clay, mixed, brown and red	8
5.	Clay, black, with chert	20
4.	Clay, lean, stratified, gray	4 to 5
3.	Clay, fat, stratified, gray	4
2.	Clay, white, sandy	6 to 8
1.	Kaolin	8 to 10

Montier. There are several abandoned clay pits on the Nicholson land three miles north of town.

TEXAS COUNTY,

Willow Springs. About 6 miles northeast of Willow Springs (Tp. 28 N., R. IX W., Sec. 3) on the Snow place, is a hill on a branch of Pine creek that exposes a mixture of yellow clay, flint, sandstone and some kaolin. Although the exposed face shows a very large amount

of flint, sandstone, yellow clay and kaolin, some excellent, soft, white, fine-grained kaolin exists, while by washing a good uniform quality is obtainable.

Sargent. Three miles east on the Olmstead land (Tp. 28 N., R. IX W., Sec. 19, SE. qr.) is an outcrop of 2 feet of white to pink kaolin, at the base of a hill. Overlying the kaolin is a mixture of chert, sandstone and some clay. The kaolin is very fine-grained, soft, lean, and from white to pink in color.

HOWELL COUNTY.

The cuts of the Kansas City, Fort Scott and Memphis railroad in Howell county, as well as those of the Current River railroad, from Willow Springs, show heavy beds of debris of insoluble matter resulting from the chemical dissolution of former limestones. The predominating material is always chert, usually in small angular fragments and sandstones that frequently appear like quartzite. Intermixed with this fragmental matter is more or less sand and clay, with occasional pure beds or pockets of the latter. The sand and sandstone usually vary from white to yellow in color, while the clays most frequently are heavily iron-stained and from yellow to red in color, and are usually very plastic. Some of the clay, especially in the deep cuts, is white to pink in color, and of a fine, lean, soft character. This white clay is usually so intermixed with chert as to be valueless as it naturally occurs, but by washing it would make a very fair quality of kaolin. The Macy clay, subsequently mentioned, is such an occurrence, where the loss in washing amounted to 13.0 per cent; but the resulting washed clay was of excellent quality, except that it had the abnormal total shrinkage of 24.0 per cent. The Yates deposit, near West Plains, is a local concentration by washing from above, and to that circumstance owes its lack of chert and other detrital matter. This overlying mixture of cherts and clays is characteristic of this county, as shown by most of the wells, as well as the railroad cuts, and prospecting is almost sure to develop bodies and pockets of kaolin of commercial importance.

The adjoining counties on the north and east, Oregon, Shannon, and Texas, and probably Douglas and Ozark on the west, have also more or less of this clay-carrying debris, and hence are likely to contain pure bodies of kaolin that have resulted from the washings.

West Plains. On the Yates land (Tp. 24 N., R. IX W., Sec. 26, NE. qr.), which is 4 miles west of town and one-half mile north of the county road, a body of kaolin over 12 feet thick was encountered in sinking a well. The well is at the foot of a small hill near the Yates

house and the kaolin was first reached at a depth of 2 feet and continued to a depth of 14 feet. It has a very dark, almost black color, which seems to be due to organic matter, as it disappears on burning. In a cellar about 200 feet east of the well, 1 to 2 feet of kaolin were found, but it was very badly intermixed with chert. A sample of the dark clay gave the following results: Color light purplish brown to dark (dry), with yellow streaks. Texture massive, compact and soft. Taste fat and slightly of alum. Slacked rapidly and completely into fine granules one-fortieth to one-tenth of an inch in size. Pyrite was not noticeable; black specks (of coal?) were sparingly scattered through it. When ground to 20-mesh and mixed with 30.5 per cent of water it made a very plastic, stiff paste that shrunk 8.5 per cent in drying and 9.5 per cent when vitrified, giving a total shrinkage of 18.0 per cent. The air-dried mud had an average tensile strength of 113, and a maximum of 126 pounds to the square inch. Incipient vitrification occurred at 2,000° F., complete at 2,250°, and viscous at 2,500°. It burned to a pure white, tender ware when vitrified, unless very slowly cooled, when it was strong. It dried rapidly. Specific gravity 1.76.

A chemical analysis gave the following results:

	Per cent.
Silica	60.55
Alumina	24.77
Combined water	12.86
Iron sesquioxide	0 84
Lime	0 25
Magnesia	0 41
Alkalies	0 68
Total	100.36

Sterling. One-half mile south of Sterling on the Macy place a well was sunk on the top of a ridge to a depth of 67 feet. From the dump it was evident that it had passed through a mixture of white and yellow clay, with chert and sandstone. A sample of the white clay gave the following results: Color white to cream (dry). Texture massive, very soft and very fine-grained. Taste rather fat and occassionally gritty. Slacks rapidly and completely into flakes and granules one-fortieth to one-tenth of an inch in size. Pyrite was not noticeable; chert occurred in lumps one-eighth to one inch in size. A sample that was washed through an 80-mesh sieve made a rather plastic paste with 35.5 per cent of water, which shrunk 9.2 per cent in drying, and 15.0 per cent when vitrified, giving the abnormally high total shrinkage of 24.2 per cent. The average tensile strength of the air-dried mud was 59 and the maximum 71 pounds to the square inch. Incipient vitrification occured at 2,250° F., complete at 2,500°, and viscous above

2,600°. It burned to a white, compact, somewhat tough, vitrified body and dried rapidly, but required to be heated slowly to avoid cracking.

A chemical analysis gave:

	Per cent.
Silica	57.75
Alumina	27.60
Combined water	11.43
Iron sesquioxide	2.09
Lime	0.24
Magnesia	0.31
Alkalies	0.60
Total	100.02

CENTRAL KAOLIN DISTRICT.

MORGAN COUNTY.

About 12 miles south of Versailles at the old Buffalo lead mines there is a pocket of white to pink kaolin. It has been worked for the past 16 years by Geo. P. Clark, of Versailles, who has shipped about 200 barrels of 350 pounds each year, to the St. Louis Stamping Co., for enamelling purposes. The deposit occurs in a basin about 40 feet in diameter and 40 feet deep. The kaolin is flaked by a sandy yellow clay, and is a soft, fine-grained, moderately plastic variety, commanding $2.50 a barrel.

COOPER COUNTY.

At Clifton City on the county road one-fourth mile south of town about 6 feet of kaolin crop out along a small branch. It is associated with fragments of flint and white sand. A sample of the kaolin examined was white, soft, fine-grained and of good quality.

SOUTHWESTERN KAOLIN DISTRICT.

LAWRENCE COUNTY.

Aurora. Five miles southwest of Aurora, on the Wisniski place (Tp. 26 N., R. XXV W., Sec. 28) a white porcelain-like clay crops out along a small branch. About one foot is exposed along the bank where it is more or less stained and intermixed with yellow clay. It seems to be a true halloysite, and it is said that samples sent to East Liverpool, Ohio, commanded $6.00 a ton. While the lack of plasticity interferes greatly with the value of this clay (halloysite) its occurrence is mentioned here as strongly indicating the existence of other large and more plastic bodies. A sample of this clay gave the following results: Color white, uniform, badly surface stained brown by iron, Texture massive, compact, hard (2.0 to 3.0) like porcelain, very fine-grained and uniform. Taste dry and very lean. Slacks not at all.

Pyrite was not noticeable. When crushed to 20-mesh and mixed with 30.0 per cent of water it made a very lean paste, which shrunk 5.2 per cent in drying, and 15.8 per cent when vitrified, giving a total shrinkage of 21.0 per cent. The dried mud had an average tensile strength of 38, and a maximum of 42 pounds to the square inch. Incipient vitrification occurred at 2,200° F., complete at 2,500°, viscous above 2,600°. It burned to a gray, compact, tender body when vitrified, and dried rapidly, but required to be heated slowly to avoid checking. Specific gravity 1.91.

A chemical analysis gave:

	Per cent.
Silica	44.12
Alumina	37.02
Combined water	18.48
Iron sesquioxide	0 33
Lime	0.19
Magnesia	0 00
Alkalies	0.24
Total	100.38

BALL OR BOND CLAYS.

The ball, bond or plastic china clays of Missouri are divisable into two classes: (1) Those derived from the accumulation of the residual matter of limestones; and (2) those derived from the weathering of the flint clays. The former have an origin similar to that of the kaolins, or at least those kaolins in Missouri. They are found in ancient depressions or sink-holes in the limestone and in the immediate vicinity of very pure white, non-ferruginous limestones. If the limestones contain pyrite, siderite, limonite or other iron-bearing minerals, which is the case to some extent with a great majority of limestones, the residual clays resulting from their dissolution are more or less impregnated with the iron, which is always altered in this case to the hydrous sesquioxide or limonite which gives such clays their characteristic yellow to brown color. It is found that clays, as in the case of most other aluminous compounds, have a keen absorptive power for color, and therefore become contaminated by the associated iron minerals in the limestone. It is only when the limestone is free from iron and the original argillaceous matter which contaminated the calcareous sediment from which the limestone was derived, is also non-ferruginous, that clays resulting from the decomposition of limestone are without color and are suitable for white-ware. If the limestone is contaminated with the spicules of sponges or other silicious remains, these are also left behind with the argillaceous impurities rendering the clay silicious, and therefore partaking more of the nature of a kaolin or

lean clay. If, however, the limestone is free from sand or other siliceous impurities, the clay is fat or plastic, and gives a ball or bond clay and this is the type of clay in Jefferson county. Although this type of ball clay has thus far only been found in the one county in Missouri, some of the Cape Girardeau kaolin closely approaches it and it is liable to be found whenever there are extensive beds of white limestone. Such limestones are usually confined to the Burlington horizon of the lower Carboniferous, or to the Trenton horizon of the Ordovician. No other limestones are now known in the state that are not in general too ferruginous to expect them to yield, by their chemical dissolution, clays sufficiently low in iron to answer for ball or white-ware bond clays. Nor are all the limestones of the Burlington and Trenton always sufficiently free from iron to yield white-ware clays. Those white ware clays occurring in Missouri are always found in direct association with one or the other of the formations mentioned, or as in the southeastern kaolin belts, on the zone of residuals that mark their former existence. Future prospecting should be confined either to the immediate neighborhood of the purest existing white limestones or along the trail of the insoluble cherts and other clays that mark the path of their former places of existence.

The second type of bond clays, or those derived from the weathering of the exceptionally pure flint clays, have a totally different origin and habit. They are due to the mechanical disintegration of the hard, non-plastic flint clays that occur so abundantly in pockets or basins in east-central Missouri, between the lines of the Wabash and the St. Louis and San Francisco railroads. The flint clays are almost chemically pure kaolins, but they are practically non-plastic, and therefore only suitable for "grog" in the refractory material. For some physical reason, the crystalline plates of the kaolinite are so coarse that even when the clay is finely ground it is almost devoid of plasticity and this coarsely crystalline structure is so eminently developed that the clay usually weathers into coarse granules and fragments or pebbles that appear to the casual observer as so much flint. Occasionally the conditions are such that freezing and thawing have resulted in the breaking up of the crystals, with a consequent development of plasticity. As this rupturing of the crystalline structure by freezing can only take place for a few feet below the surface, the deposits of bond clay are always superficial and change into the hard, unaltered flint clay within a few feet. The conditions favorable for this mechanical disintegration are exceptional. It is necessary that the outcrop of the clay should be depressed below the general surface, so as to hold water, and be sufficiently shallow to be reached by the frost. As the hard flint clay is

frequently more resistent to the action of erosion than the surrounding limestone, the basins are usually in relief, or are convex, rising above the general level, and therefore shed the water, so that the small amount of plastic clay that may arise from frost action on the surface is removed or washed away as fast as it is produced. Again, if the flint clay is so deeply buried that it is not reached by the frost no mechanical disintegration takes place, and no plastic clay results. Consequently the majority of the flint clay basins are hard and non-plastic and it is quite the exception for them to be covered with from 2 to 6 feet of bond clay. The bond clay resulting from the flint clays is very pure, but not satisfactory unless washed, as it is often contaminated with fragments and nodules which are eliminated in the washing process. It also has an excessive fire-shrinkage, which may be as great as 14.0 per cent, which together with an air-shrinkage of from 2.0 to 6.0 per cent gives a total shrinkage of 12.0 to 20.0 per cent, a very dangerous and critical amount to contend with. As they are not plastic to a very marked degree, and as such an excessive shrinkage is likely to cause checking if not cracking in drying and burning, these clays have to be used with the greatest caution, and preferably in admixture with very silicious kaolins that have a very low shrinkage.

JEFFERSON COUNTY.

Mandel Ball-Clay Pit. At Regina (Tp. 41 N., R. IV E., Sec. 6, NE. qr.) on Bellew creek which is about 9 miles northwest of Hillsborough is the Mandel ball-clay pit. This is the largest and most important bank of ball-clay that has been opened in Missouri, as it is claimed to have produced over 20,000 tons. The clay is of an excellent quality and has met with a ready sale at East Liverpool and other potting centers. The pit was opened in 1880, since which time it has been successfully worked, in spite of having to contend with a wagon haul of 13 miles over heavy roads to reach the railroad at Victoria. The output has been approximately as follows:

Year.	Tons.	Year.	Tons.
1880	700	1887	1,500
1881	700	1888	1,500
1882	1,500	1889	1,500
1883	1,500	1890	3,000
1884	1,500	1891	3,000
1885	1,500	1892 (Not worked).	——
1886	1,500	Total	19,400

The clay pit lies in a small ampitheatre at the base of a white limestone hill, that rises to a height of 100 to 175 feet, and which is covered with flint, ocher and red clay. The pit is elliptical with a

maximum length in an east and west direction of 150 feet, a width of 120 feet and a depth at present to the water of 25 feet. It is said to be 20 feet farther to the bottom of the clay. The sides dip toward the center, which fact indicates that it is a typical basin or old sink-hole in the limestone. The sides of the pit are flanked with sandstone which dips at 40° to 80° toward the center of the pit. It is a soft, coarse-grained, ferruginous rock, which on the north and west sides of the pit is locally altered to a quartzite-like material. This sandstone is only 10 to 15 feet in thickness, as exposed in the cut at the south end made for the operation of a wire-rope tramway. Fragments of lignite and stones are occasionally found in the clay, indicating that the clay bottom had choked up the bottom of the sink-hole, or that it was a small pond during the deposition of the clay. In one instance a tree trunk 16 feet long and 15 inches in diameter was found embedded in the clay, while bowlders of limestone of several tons weight have been encountered, requiring blasting in order to remove them. Concretions of pyrite crystals occasionally occur and have to be carefully sorted out, while black clay stained by organic matter occurs at irregular intervals. The clay becomes ferruginous toward the sides near the sandstone and has to be sorted out as No. 3 grade, or is thrown away if badly iron-stained. The clay is worked by pick and shovel and hauled out by an inclined tramway to a weathering pile. It is then sorted into three grades, the best of which brings $7.00 a ton in St. Louis, and is stored in sheds. The best clay occurs in the center of the pit as the clay becomes more or less slightly ferruginous or iron-stained at the sides. After weathering for three or four years, the third-grade clay becomes salable from the elimination of part of the iron with which it is stained. The hoisting of the clay up the incline is done by a 10-horse-power engine. The clay is hauled in four-horse wagons to Victoria, on the St. Louis, Iron Mountain and Southern railroad, 13 miles distant, the cost being $2.25 a ton. As a part of the road is very poor and hilly only 4,000 pounds are hauled at a load in good weather and 2,000 pounds in bad weather. Storage bins along side the railroad track at Victoria hold sufficient clay to tide over the winter's demand, so that the plant is only operated during the summer season.

A sample of this clay gave the following results: Color light gray, uniform. Texture massive, uniform, not very compact, and very fine-grained. Taste smooth and fat. Slacks readily and completely into one-tenth to one-fiftieth of an inch granules. Pyrite is present in occasional grains one-fiftieth to one-thirtieth of an inch in size, but occurs sparingly. When crushed to 20-mesh and mixed with 23.0 per

cent of water it made a plastic paste that shrunk 7.7 per cent in drying and 12.2 per cent when vitrified, giving a total shrinkage of 19.9 per cent. The air-dried mud had an average tensile strength of 150 and a maximum of 175 pounds to the square inch. Incipient vitrification occurred at 1,800° F., complete at 2,100°, and viscous at 2,400°. It burned to a tough, dense, white ware when vitrified, and dried rapidly, but required to be heated slowly to prevent checking. Specific gravity 1.90.

A chemical analysis gave:

	Per cent.
Silica	45.97
Alumina	36.35
Combined water	12.36
Iron sesquioxide	1.08
Lime	1.14
Magnesia	1.09
Alkalies	1.84
Total	99.83

Morse Mill. Near the Morse mill on the Johnston place, there are said to be two prospects that show 2 feet of white china clay, which is claimed to be similar to the Regina deposit.

DeSoto. At the Mammoth mine 7 miles southwest of DeSoto (Tp. 39 N., R. III E., Sec. 12) considerable white china or ball clay was encountered in the lead diggings. The principal workings of this celebrated but now abandoned lead mine followed a channel for about 2,000 feet that was worked through four shafts varying from 8 to 12 feet in depth. This channel was more or less filled with galena, zinc blende, heavy spar, pyrite, limonite and white clay. The metallic minerals occupied the upper portion of the pipe or channel and beneath the mineralized horizon more or less white clay was encountered. The mine has been abandoned for several years and the hoisting machinery and concentrating mill have been removed. It is stated that the white clay is a thick deposit and that there is a large body of it that follows the lower portion of the old water channel. As the St. Louis, Iron Mountain and Southern railroad is only about three miles distant (Vineland), with a down grade the entire way, it is quite likely that the mine could be profitably reopened, if jointly worked for the china clay, lead, zinc and heavy spar. It is stated that about 100 cars were shipped to Cincinnati, East Liverpool and Newark, N. J., and that as much as 40 feet of clay was met with in one shaft. It sold for $7.00 a ton.

The following results of a sample collected from a bin containing about 4 tons showed it to be an excellent quality of ball clay: Color white (dry) and very uniform, with slight brown superficial stains.

Texture massive, rather compact, soft (1.5), very fine-grained and uniform. Taste very fat and very slightly gritty. Slacks rapidly and completely into flakes and fine grains one fiftieth to one-tenth of an inch in diameter. Pyrite, sand and mica were not visible. When crushed to 20-mesh and mixed with 23.5 per cent of water it made a stiff, very plastic paste that shrunk 7.7 per cent on drying, and 8.8 per cent when vitrified, giving a total shrinkage of 16.5 per cent. The air-dried mud has an average tensile strength of 198 and a maximum of 228 pounds to the square inch. Incipient vitrification occurred at 1,800° F., complete at 2,100° and viscous at 2,400°. It burned to a compact, strong white body when vitrified, dried rapidly, but required to be heated very slowly to avoid cracking. The specific gravity is 1.69. A chemical analysis gave the following:

	Per cent.
Silica	49.04
Alumina	34.85
Combined water	12.33
Iron sesquioxide	0.71
Lime	1.33
Magnesia	1.04
Alkalies	0.85
Total	100.15

FRANKLIN COUNTY.

Union. About one and one-half miles north on the Berghorn place (Tp. 43 N., R. I W., Sec. 23, NW. qr.) is a pocket of flint fireclay, of which the upper 4 to 8 feet are soft and plastic. It is a typical basin or pocket that seems to have been a sink-hole that became choked up and in which the fine sediment that filled the central portion of the basin was a very pure clay, while the sand and coarse silt fringed the edge and now forms a lining that flanks the sides; in short, it is simply a softened pocket of flint clay. A shaft has been sunk to a depth of 21 feet, which gives the following section:

		Feet.
4.	Soil	1
3.	Clay, soft and plastic	4
2.	Clay, moderately hard to very hard	15
1.	Clay, green, shaly	1

The soft, plastic clay merges imperceptibly into the hard non-plastic portion. The pit has been leased by Buck and Whitson at a royalty of $1.00 a car, and a limited amount of clay has been shipped since it opened in 1891. The following results were obtained from the sample examined. Color very light gray and uniform, with slight black stainings of probably organic nature. Texture compact, massive, soft, uniform and very fine-grained. Taste smooth. Slacks very

slowly and imperfectly to one-tenth to one-half of an inch pieces. Pyrite was not noticeable. When ground to 20-mesh and mixed with 15.5 per cent of water it made an extremely lean paste that shrunk 3.2 per cent in drying, and 9.6 per cent when vitrified, giving a total shrinkage of 12.8 per cent. The air-dried mud had an average tensile strength of 49, and a maximum of 59 pounds to the square inch. Incipient vitrification occurred at 2,200° F., complete at 2,400°, and viscous at 2,700°. It burned to a strong, white body when vitrified, and dried rapidly but needed slow and careful burning to avoid checking and cracking. Specific gravity, 1.98. A chemical analysis gave:

	Per cent.
Silica	44.14
Alumina	39.86
Combined water	13.84
Iron sesquioxide	0.46
Lime	0.77
Magnesia	0.46
Alkalies	0.76
Total	100.29

Dry Branch. About one-fourth mile north of Dry Branch (Tp. 41 N., R. I W., Sec. 8, SW. qr.) is the Peterson flint fire-clay bank. The upper 2 to 4 feet of this flint clay has weathered into a soft plastic ball clay. The clay is covered by 1 to 3 feet of chert, over which are 3 feet of soil. About 1,000 feet southwest of the above pit a smaller flint clay deposit has been opened of which the upper 6 to 9 inches have weathered into a plastic ball-clay.

CRAWFORD COUNTY.

Leasburg. About one and one-half miles north of Leasburg (Tp. 39 N., R. III W., Sec. 3) is the Rowden flint fireclay pit. The upper 1 to 4 feet of clay have weathered into a soft plastic ball-clay which merges into the hard fireclay. Full details of this deposit are given in connection with the consideration of the flint clays.

WARREN COUNTY.

Truesdale. About four miles southeast of Truesdale (Tp. 46 N., R. II W., Sec. 11) is the Connell china clay pit. It was discovered by outcroppings in 1893, and a small excavation 7 feet deep was sunk in it. It is a soft, white, plastic clay, but is badly contaminated with fragments of limestone that are from 6 to 18 inches in size. It also contains concretions of lime and dolomitic sand, and is stained with green streaks and yellow iron stains that would require careful sorting to eliminate. The clay undoubtedly occupies a basin or old sink-hole in

the limestone which is probably Trenton in age. The limestone fragments and concretions could be readily eliminated by washing the clay, but it seems to be generally contaminated with carbonate of lime as it effervesces with acid. The clay is light gray with occasional dark spots, fine grained and plastic. It burns to a white, dense, strong body and readily vitrifies, but with the formation of gas blebs due to the escape of carbonic acid. This latter fault could probably be remedied by very slow water-smoking. Incipient vitrification occured at 1,600° F., and complete at 1,800° F. The close proximity of outcropping limestone indicates that this basin or pipe of clay is very limited. It is more valuable as a prospect for what it may develop into, than for the intrinsic merit of the clay that is in sight at present.

FELDSPAR DEPOSITS.

On account of the intimate relations between feldspar and the china clays in the manufacture of white ware, the following known and prospective occurrences of feldspar in Missouri are given. Thus far only one workable deposit has been found and this is in Ste. Genevieve county. But from the very extensive series of plutonic and feldspathic rocks in southeastern and central Missouri, it is highly probable that other workable deposits exist. The granite rocks especially are likely to contain segregated veins of feldspar, particularly if they are of the coarsely crystalline or pegmatitic type, that is known to occur in Camden county. It is also possible that some of the porphyries may be sufficiently free from iron-bearing minerals to answer for "spar." But this is far less promising if white-ware is to be made, as the porphyries are nearly always contaminated with sufficient quantities of iron-bearing minerals to discolor the ware. Should Missouri feldspar deposits develop into large producers, it would not only be of very great importance to the potteries that are likely to develop in the state, but also to the potteries in Illinois, Indiana and Ohio, as the class of rocks in which they occur are not found nearer than Wisconsin on the north, the eastern ridge of the Alleghanies on the east, central Texas on the south, and the Rocky mountains on the west. Missouri enjoys the unique distinction of having the only granite outcrops in the great Mississippi valley, excepting a small area in the northeastern part of Indian Territory.

Ste. Genevieve county. Two miles east of Jonca on the Dobschutz land (Tp. 36 N., R. VII E., Sec. 10, SW. qr.) is a red granite containing a segregated vein of feldspar. It was found by a resident, Mr. Wm. Watts, over 15 years ago, and was opened and worked during the brief life of the Belleville pottery, where it was exclusively used. A

pit has been opened on the feldspar vein, that is 35 feet deep. The vein is said to have been lenticular, with a maximum width of 8 feet and to have tapered to one and-half feet at the north end. It occurs in a red granite devoid of mica, of which the quartz is white and the feldspar light to deep red. Some of the spar is of excellent quality. It was found to fuse at 2,200° F., into white, tough glass. A very serious defect to its profitable development at present is the lack of shipping facilities, as it is 20 miles from Ste. Genevieve on the Mississippi river, and about 12 miles from the nearest railroad. An old railroad survey passes close to the property and active steps are shortly expected to be taken toward its construction. The experience of the Belleville pottery was very satisfactory, and the laboratory tests endorse this trial. An analysis furnished by Mr. Dobschutz is as follows:

	Per cent.
Silica	64.80
Alumina	18.00
Potash (traces of soda)	15.90
Water	0.70
Lime, Iron, Magnesia	0.60
Total	100.00

Camden County. On the border line between Camden and Laclede counties (Tp. 37 N., R. XVI W., Sec. 22, SW. qr.), on the Wheeler place is a low, dome-shaped outcrop of pegmatitic granite. The feldspar is a white to delicate pink or flesh in color. It has the same disadvantage as the Ste. Genevieve deposit, however, in being a long distance from the railroad as the nearest shipping point is Lebanon, a distance of 15 miles direct or 20 miles over fairly good roads. The outcrop furthermore is limited, covering only about an acre, and outcrops of limestone within 500 feet show that prospecting will have to be done mainly with a diamond drill.

ADVANTAGES OF ST. LOUIS AS A POTTERY CENTER.

St. Louis has natural advantages for the manufacture of whiteware pottery that are enjoyed by no other district in the country and when they are better known the city is destined to become an important potting center. In the westward travel of the Star of Empire, this particular industry, which is still largely in the hands of Englishmen, has failed to keep pace with the growth and development of the West. St. Louis owes its first development to its river facilities, but its larger and more important manufacturing industries were held in check until the bridging of the Mississippi river in 1874. Since then the manufacturing interests have shown a growth and development

that have been commensurate with its mercantile advantages. Recently a new manufacturing district has been opened up and among the industries that should result from these important shipping facilities, should be the home production of white-ware from Missouri clays.

The white-ware industry in the United States began at Trenton, N. J., midway between the two large markets of New York and Philadelphia, and in close proximity to the famous Amboy clay beds. From there it traveled westward to East Liverpool, Ohio, where the common grade of yellow ware (known as "Rockingham") made from the local clay, caused such severe competition as to force some of the potters into white-ware, in which they had the advantage over Trenton in freights. This resulted in finally building up by a slow but steady growth, a second potting center that has outstripped Trenton in magnitude, and which has not only captured the western trade but has also entered the eastern or Trenton territory to a considerable extent. While these two places, Trenton, N. J., and East Liverpool, Ohio, are the principal producers of white-ware to the extent of about two-thirds of the total output of the country there are a number of potteries that have drifted further west to western Ohio, Indiana and Illinois and the most western pottery is that at Peoria, Illinois, 187 miles north of St. Louis.

The numerous scattered potteries have successfully met the only objection to St. Louis, namely, the present lack of experienced potters. This lack, which is felt by all pioneer factories, disappears with time and growth, and has never proven an obstacle of importance in the development of any industry. If it did, the West would be still dependent on the East for all its manufactured products, and in fact the United States today would be exclusively an agricultural country, and dependent on the industrial centers of Europe. The disadvantage of having to break in new men, or to get along with the poor class of journeymen that drift into new outlying districts, is only temporary and under energetic experienced foremen can be readily overcome. Being only transitory it has always proved of minor importance, when compared with the permanent mercantile advantages of reduced freights, short hauls, home markets, and cheap raw materials, and the latter are the conditions that St. Louis enjoys over every other potting center. St. Louis has the following great advantages as a potting center:

(1) Cheap raw material, as kaolin, bond clay, feldspar and flint, which are all found in Missouri.

(2) Cheap fireclay and fire brick, for the saggers and kilns, as St. Louis is not only one of the largest fireclay producers in the United States, but one of the cheapest.

(3) Excellent cheap fuel.

(4) Large home market.

(5) Unexcelled shipping facilities, by being the center of the most extensive rail and river systems of any city in the country.

In elaborating these advantages, kaolin is not only found in numerous places and in large amounts in the southern and southeastern districts, but it has been shipped for several years in large quantities to Peoria, Cincinnati, East Liverpool and other potting towns, to be made up into ware that is shipped back to Missouri, thus paying not only double freights but the additional expense of wastage and breakage at the pottery.

Bond-clay is found in several places in the southeastern part of the state. It has likewise been extensively shipped to eastern potteries, to be made up for shipment back to the state. These two classes of white-ware clays are now shipped to eastern potteries from 185 to 600 miles distant. This foreign and return freight would alone pay a profit of 10 to 15 per cent.

Feldspar of excellent quality has been found in Ste. Genevieve county that was used with success in the Belleville, Illinois, experiment, and under the stimulus of a home market, could be profitably worked. It is also very likely that prospecting would develop other veins of feldspar in southeastern and central Missouri, where the feldspathic rocks are very abundant, as shown in the numerous outcrops of granites and porphyries.

"Flint" is very abundant in four different forms: (1) as chert or flint fragments, beds, and masses covering limestone; (2) as very extensive beds of very pure white sandstone, "Saccharoidal;" (3) as pockets of very fine, white, decomposed chert known as "silica" in southeastern Missouri; and (4) as veins of quartz in the granite and porphyry in southeastern and central Missouri. No other pottery center has such a variety of raw materials in such close proximity as St. Louis, which within 30 to 130 miles is able to command all the constituents that enter into the highest grade of pottery. Trenton, N. J. has to send to the port of New York for the English china clays, to North Carolina for the Ashville kaolin, and to Pennsylvania, Rhode Island, or Maine for its flint and feldspar, which are from 60 to 700 miles distant. East Liverpool has to send to these same places for its raw material, with the disadvantages of even longer hauls, or from 300 to 500 miles.

The first cost and repairs of the kilns make up a serious item in the pottery business, and the outlay for saggers is still greater. St. Louis is the only city in the country that has a clay suitable for these

purposes within the city limits, while Trenton which ranks second in this respect has to send from 25 to 40 miles for this class of clay. Furthermore, the fireclay required for saggers is cheaper in St. Louis than in any market in this country, on account of a thick seam of excellent grade outcropping at about water level, in the western and northern parts of the city. Mine run of good quality fireclay can be bought and delivered at the works for 75 cents to $1.00 a ton, and a selected quality for $2.00 to $3.00 a ton.

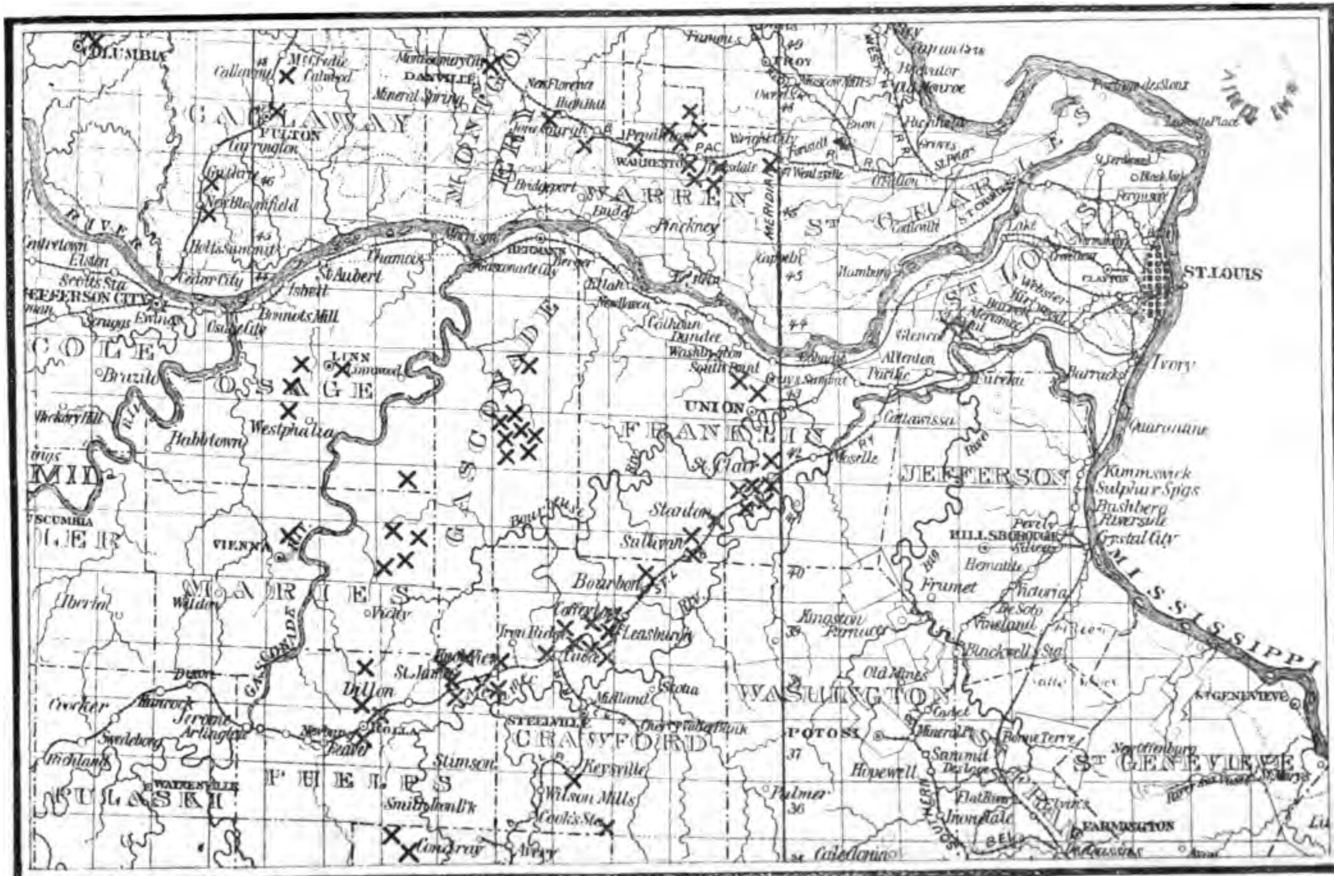
An excellent quality of bituminous coal is shipped into the St. Louis market from the Big Muddy district, in southern Illinois, that sells for $2.00 to $2.25 a ton. It is an excellent free-burning coal that is low in sulphur and while not equal to the Pittsburg coal in quality it has been successfully used for burning whiteware at Belleville and Cape Girardeau. The ideal fuel for burning pottery is gas, but the sad experience of gas districts is that the wells are short-lived, and for permanency, a good coal must be relied upon. Taking this into consideration St. Louis is quite as favorably situated in respect to fuel as Trenton and East Liverpool, and more so than most other pottery centers.

The city of St. Louis, with its immediate surroundings, includes a population of about three-quarters of a million, which alone would absorb the output of several potteries. In the potting business a local market is a great advantage, as it decreases the expense of packing, the carrying of extensive stocks, and the cost of collections. It is a most desirable outlet for a pottery in which it enjoys a great advantage over Trenton and East Liverpool.

As regards water transportation no inland city has access to the area and population that is enjoyed by St. Louis, as it is the center of the largest river system in the world. Its waterways reach as far north as St. Paul, on the upper Mississippi, with its tributaries; in the south to New Orleans on the lower Mississippi, in the east to Pittsburg on the Ohio, with its tributaries; to Chattanooga on the Tennessee, with its tributaries; to Fort Smith on the Arkansas, with its tributaries; and in the west to Bismarck in North Dakota on the Missouri, with its tributaries. While all these rivers are more or less interrupted by ice in winter, and by low water in summer, they are of very high value in restraining and keeping down railroad rates, and giving access to many small towns at or near the river that as yet have no rail connections.

As a railroad center St. Louis is equalled by no other city in the country, as eighteen trunk lines radiate from it in every direction, which with their branches open up the heart of America to St. Louis. The

new and rapidly developing southwest territory which St. Louis monopolizes is a special feature of this metropolis. This immense railroad system alone is of inestimable value in successfully carrying on any business, and is the secret of Chicago's phenomenal development. St. Louis should attract the potter if it had no other advantage but this, as the railroads are pre-eminently the life of trade and the avenues to success. When to this is combined its proximity to all kinds of raw materials of excellent quality, with an abundance of cheap fireclay within its walls, with one of the cheapest fuel markets in the country, and a large, rapidly growing local market, the active, enterprising, energetic potter can no longer afford to ignore these advantages. The first potteries established in St. Louis will naturally take advantage of the local market, in which are the largest profits; but the followers of the successful pioneers will have this vital advantage over other locations, that the incomparable shipping advantages will enable them to successfully compete against any other potting center in the markets of the great Mississippi valley.



SKETCH MAP OF THE FLINT CLAY DEPOSITS.

CHAPTER IX.

FLINT OR NON-PLASTIC FIRECLAYS.

The flint, rock, or non-plastic fireclay of Missouri is unique in mode of occurrence. It usually has a remarkably pure chemical composition, and is devoid of the chief characteristic of clay, or plasticity. The name "flint" clay is very appropriate as regards the appearace as it has a compact, dense, comparatively hard structure, and breaks with a sharp, conchoidal fracture that resembles flint. When ground and mixed with water it usually has no more plasticity than so much fine sand, and in consequence it can not be used alone as it cannot be moulded. It is necessary to mix it with a bond, fat or plastic clay which acts as a binder or cement to the particles of flint clay.

After flint clay has been calcined to remove the excessive fire shrinkage it is very valuable as a grog in refactory ware, for which purpose it is exclusively used. Its exceptional purity would make it very valuable in the manufacture of white-ware if it could be moulded, when it would command a very much higher price, but having to compete with old firebrick and the plastic fireclays it usually sells for only $1.00 a ton on board the cars at the clay bank, which is an extremely low price for material of such exceptional purity. It is extensively shipped to the St. Louis and Chicago markets and is sold to a limited extent in Indiana and Ohio, but the freight prohibits its being shipped greater distances.

The flint clays occur in the central portion of the state, more particularly in the east-central district, with Gasconade county as the center. They are very abundant in Warren and Montgomery counties along the Wabash railroad, in Callaway county on the Chicago and Alton railroad, in Osage county on the Missouri Pacific railroad, and in Franklin, Crawford and Phelps counties, on the St. Louis and San Francisco railroad, as shown in the accompanying sketch map (plate VI). These are the principal producers, but other deposits are known which extend as far north as Monroe county, as far west as Morgan and St. Clair counties and as far south as Dent county.

The deposits are not confined to a particular geological period. They occur in the lower Carboniferous, in the extensive deposits along

the Wabash railroad; in the Silurian, in St. Louis and Franklin counties, and in the Ordovician, in Gasconade, Osage, Crawford and Phelps counties.

MODE OF OCCURRENCE.

The similarity of the deposits is very striking, as they all occur as pockets, basins or isolated areas of limited extent. They are never found in stratified beds or sheets that extend over large areas as in the case of the plastic fireclays and shales. They have an irregular, massive, jointed structure that seldom suggests a water-laid deposit. They always occur in limestone formations and occupy local sink-holes or crater-like depressions, that in size and shape are identical with the numerous sink-holes that are so characteristic of many of the Missouri limestone districts. The basins occupied by flint clay vary from 50 to 200 feet in diameter, and from 15 to 50 feet in depth. An idealized

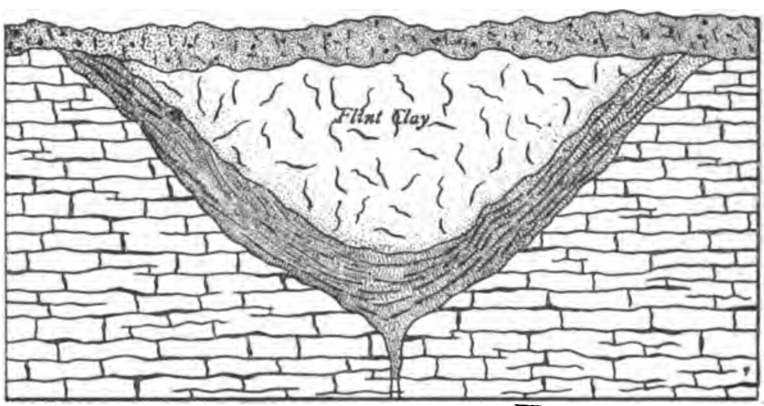


Figure 9. Section of Typical Flint Clay Deposit.

section is shown above (figure 9). Between the limestone wall of the basin and the central mass of flint clay there is usually a sheet of highly inclined sandstone that is several feet in thickness and conforms to the slope of the basin, or approximately thereto, and merges into the clay, as there is usually a mixed layer of a few feet of sandy clay between the pure flint clay and the sandstone. The evidence very strongly suggests that these flint clay deposits occupy former sink-holes in the limestone, the underground outlet of which became clogged or choked, thus converting them into small ponds or lakelets that have confined the drainage of the contiguous country. The sandstone that usually lies between the limestone sides of the pocket and the central body of flint clay conforms in dip to the more or less steep slopes of the limestone basin. The transition layers of mixed sand and fireclay, though only a few feet in thickness, and the pure central body

of flint clay is highly suggestive, in fact is nearly conclusive evidence, of the sedimentary origin of the clay. In a quiet woodland pond there would be practically no movement of the water, and if the character of the material that drained into it did not vary, no planes of sedimentation would arise even though the supply of material was more or less intermittent. The material could therefore accumulate to an indefinite thickness without the formation of stratification planes, while the subsequent desiccation of the mass would cause the irregularly jointed, conchoidal structure that is so characteristic of the flint clays. Stratification planes are sometimes present and though not always perfectly developed, they tend to take a local variable dip that conforms to the limestone sides. Strong as the evidence seems to be in favor of the mechanical deposition of pure clay silt in the central portion of the choked-up sink-hole there are some other features that are difficult to explain on this hypothesis, of which two of the most important are the remarkable freedom from impurities, and the abnormally high amount of alumina which the flint clays nearly always exhibit.

CHEMICAL COMPOSITION.

The flint clays have a remarkable composition. The average of twelve working samples scattered over seven counties shows only two per cent total impurities; while four of the samples contained less than one per cent. Such remarkable purity over extended areas in so many different isolated bodies is a difficult feature to explain on the sedimentation theory, especially as the specimens were large, working samples from the entire face of the bank. While such exceptional purity is not unknown, it is generally local, and rarely extends over extensive areas. Most published analyses are from selected or picked samples and are consequently misleading in indicating greater purity than the average of the deposit. Pure kaolinite is supposed to contain 39.8 per cent of alumina, according to Dana and most other accepted authorities; while eight out of twelve Missouri flint clays contain from 39.86 to 43 22 per cent. With this abnormally high alumina is usually associated an abnormal amount of water, which is found to range from 14.0 to 14.94 per cent, while pure kaolinite has only 13.9 per cent. This high alumina and water is at the expense of the silica, which is abnormally low, less than the 46.3 per cent, the amount that is contained in pure kaolinite. These three features of the abnormally high alumina and water, and abnormally low silica, are only found in the flint clays. There is some doubt, however, as to the exact chemical composition of

kaolinite, as Bristow in his "Glossary of Mineralogy" (p. 199) gives the following composition of kaolinite:

	Per cent.
Silica	40.0
Alumina	44.5
Water	15.5
Total	100.00

If this should be accepted as the correct analysis of kaolinite it would include all the flint clays, but Bristow is an accomplished compiler, rather than an authority. Dana formerly described and gave the analysis of a mineral very similar to kaolinite which he called pholerite that had the following composition:

	Per cent.
Silica	39.3
Alumina	45 0
Water	15.7

As the physical properties of kaolinite and pholerite are identical, the flint clays if judged from their analyses, seem to be variable mixtures of these two minerals, which would clearly explain their composition. But Dana ignores the existence of pholerite in his last edition (1893), and calls it a synonym of kaolinite, notwithstanding the citation of five analyses in his earlier edition that show from 41.3 to 45.85 per cent of alumina. The beauxite series of alumina minerals offers considerable assistance in explaining the variation in the composition of kaolinite (or pholerite), for it presents a range from almost pure hydrous oxide of alumina at one extreme, to pure kaolinite at the other, with all the intermediate variations in composition, although consisting mainly of hydrous oxide with only a minor portion of alumina in the form of silicate. This variation has been satisfactorily explained upon chemical grounds, from the decomposition and more or less complete abstraction of the silica from the kaolinite. The usual pisolitic concretionary structure is indicative of their probable chemical derivation.

Another peculiar chemical feature of the flint clays is the very frequent contamination by red oxide of iron. The iron-stained portion occurs rather irregularly with a sharp line of demarkation between it and the light gray unstained portion, and usually only a minor portion of the marginal part of the deposit is thus ruined for refractory purposes (as it runs as high as 3.0 to 13.0 per cent in ferric oxide). The usual condition of the iron in clays and shales is either as the brown or yellow hydrous oxide, or limonite, which is nearly always the condition in limestone formations; or as pyrite, or the bisulphide, in most of the non-oxidized fireclays and many shales; or as siderite, or carbonate, as in most shales. Associated in the same formation and similar in mode of occurrence (or in isolated pockets or sink-holes in

sandstone and limestone) are deposits of hematite, or red oxide of iron. Occasionally the iron is a specular blue oxide when it is in a dense, hard condition, or is the bright red oxide when it is in a soft condition, but in both cases there is a fringe of sandstone between the iron ore and the surrounding limestone, similar to the deposits of flint clay. When there is no sandstone and the iron rests directly on the limestone it is always in the form of brown ore, limonite, or hydrous oxide. As the iron banks are of undoubted chemical origin and are not infrequently more or less contaminated with clay, in fact occasional transitions are found between very clayey iron ore and highly ferruginous flint clay while the mode of occurrence is identical, it strongly points to a probable chemical origin of flint clay.

The close, dense structure, exceptional hardness (from 2.5 to 3.5), sharp conchoidal fracture and lack of plasticity are marked features which distinguish the flint clays from the usual normal type of fireclay, and which are all easily explained on the chemical precipitation theory. The excessive density ranges from 2.33 to 2.45 and averages 2.38, which is very exceptional in view of the fact that they are surface deposits and have never been subjected to the pressure of great overlaying masses, as in the case of most other clay deposits. Recent clays, the lœss, gumbo, glacial and residual clays, which have had little or no weight over them, have a specific gravity of 1.69 to 2.20, while the coal measure fireclays, potters' clays and shales, which have been subjected to the pressure of great overlying masses, range from 2.25 to 2.55.

The absence of plasticity in the flint clays finds occasional parallels in the normal coal measure fireclay beds. In the famous Mount Savage fireclay seam of Maryland, according to Cook*, part of the seam is plastic and part of it is non-plastic. The seam varies from 8 to 20 feet in thickness and the hard, non-plastic, and the soft plastic portions are very irregular. Usually the soft clay lies on top of the hard non-plastic clay, and while at times there is a sharp line between the two, in other instances they merge into each other. The hard non-plastic clay has an irregular conchoidal fracture and it is not plastic unless ground to an impalpable power and when weathered for several years it only crumbles slightly and is affected only from 3 to 4 inches from the surface. The Kittaning fireclay seam of Ohio, according to Orton,† furnishes a clay that is generally plastic, but it is more or less intermixed with hard or flint clay in Stark, Tuscarora and Carroll counties. In the vicinity of Fulton, Callaway county, Missouri, there

*Trans. American Inst. Mining Eng., vol. XIV, p. 698.

†Geol. Sur. Ohio, vol. VII, p. 65, 1893.

is a similar transition between the normal type of plastic fireclay, and the hard non-plastic flint clay where a thick, coal-measure fireclay seam thins out into semi-plastic and finally non-plastic pockets. While these transitions from plastic to non-plastic fireclays in Maryland, Ohio and Missouri increase the difficulty of accounting for the marked differences between the plastic and the flint clays, the pronounced and general non-plastic character of flint clays is at least suggestive of their chemical origin. But when the flint clays are examined microscopically they are found to have a coarse plate structure which is known to be very unfavorable to plasticity; although when these coarse plates are broken up into fine scales, either by prolonged weathering action or by fine grinding, the same clay is rendered plastic. Hence the local variations in the beds of plastic and non-plastic clay may be due to the bed having been penetrated by solutions that have chemically acted on the plastic portion of the clay with the result of secondary crystallization of the kaolin, or it may be due to chemical disintegration of portions of non-plastic or flint clay bed.

The hypothesis which seems most plausible for the origin of the Missouri flint clay deposits is that they are primarily sedimentary deposits in sink-holes that have been subsequently slightly altered chemically by leaching, with a recrystalization of the kaolinite. The clay has been derived from the chemical disintegration of the limestones in which they occur, the residual clay of which has gradually washed into the sink-holes that drain much of the limestone regions; and when these have not been choked such clays are to be found as stratified bodies lining the channels or caves that are the underground outlets of the sink-holes. When the sink-holes have become choked or clogged as frequently happens this silt accumulates in the bottom more or less rapidly, according to the topography, the resistance and purity of the limestone. In most cases, on account of the gentle plateau character of the surface, the rate of accumulation would be very slow, during which the clay would be constantly exposed to the prolonged action of surface waters, which with its greater or less charge of carbonic acid, would have a strong solvent action on the lime, magnesia, iron and alkalies, and seemingly also on the silica. The coarse silicious matter that is found in most limestones would be washed into the sink-holes at much less rapid rate on account of the size of the particles and the gentleness of the topography and would immediately settle as deposits of sand on reaching the edge of the sink-holes and thus form the sandstone fringe that more or less thickly lines all the pockets of flint clay.

As the sink-holes are perfectly quiet woodland pools, and are absolutely devoid of currents (barring insignificant surface movement from the wind) there would be no opportunity to form stratification planes no matter how slow or intermittent the deposit may have grown, if it did not vary in character. The impalpable fineness of the clay particles would cause them to settle out in the central portion of the pool and also to a slight extent with the quickly falling sand particles along the fringe of the basin which would give the transition from the sandstone border to the purer central masses of clay. The very slow rate of accumulation of the clay in such an enormous excess of pure surface water with its high charge of carbonic acid is the probable reason that the leaching of the soluble constituents of clay has been so thorough. As the water-filled sink-holes are usually remarkably free from growing vegetable matter there is no opportunity for its accumulation to the extent that discolors most swamp or shallow water deposits, and hence the usual whiteness of the clay when not contaminated with iron.

In the accumulation of the silt that has formed the coal measure clay seams in swamps or estuaries, there has been a growth of vegetable life that has nearly always stained it dark, though in actual amount it may not exceed 1.0 to 3.0 per cent. In a few instances some of the Missouri flint clays have been found similarly stained by vegetable matter and such clays are always much less pure than the white clays, which indicates a much more rapid accumulation of the deposit, and hence an insufficient time to leach out the impurities. This is illustrated in the Sankey (Crawford county) and Owensville (Gasconade county) flint clays which are black in color and low in density (specific gravity 2.10) and high in fluxing impurities, or from 5.29 to 6.85 per cent. In the chemical alteration of the silt there has been a recrystalization, which, taking place slowly, has resulted in large crystals, hence the lack of plasticity in the flint clays, and their much greater density and hardness than if they had been merely rapidly formed as superficial deposits.

PHYSICAL PROPERTIES.

The flint clays have a characteristic structure that differs from all other clays. In place they are massive and devoid of the lamellar or bedding planes that are usually found in shale and some fireclays (plate VII). They have a conchoidal to splintery fracture, a close, dense structure, and a hardness of 2.5 to 3.5. They are totally devoid, even when wet, of the greasy feel that is characteristic of most clays and they are unique in not slacking or disintegrating into powder when

dry fragments are immersed in water. Their specific gravity is usually very high ranging from 2.33 to 2.45 when in their normal condition, though an impure black clay from Crawford county (Sankey bank) was as low as 2.10.

The plasticity of the flint clays is usually so feeble that they can not be used alone, but have to be mixed with a bond or fat clay, in order to be moulded. This is well shown by their tensile strength ranging from 10 to 38 pounds to the square inch, whereas plastic clays range from 100 to 200 pounds. Occasionally at the outcrop they weather for a few feet to a semi-plastic condition, from the disintegrating action of the frost, when they show a strength as high as 59 pounds. If they are ground very finely the plasticity is materially improved, as shown in the Garstang sample, which had a strength of 25 pounds when ground to 20-mesh, or was extremely lean, but when ground to 100-mesh had a strength of 65 pounds or was moderately lean, and was capable of being moulded, if worked slowly and carefully. The water required to develop this meagre plasticity ranged from 15.0 to 17.0 per cent which is very low. The shrinkage in drying out this amount of water is very low, from 2.5 to 3.5 per cent. The shrinkage in burning is very high from 9.0 to 14.0 per cent and averages 10.0 per cent which gives an average total shrinkage of about 13.0 per cent. This is so excessive that it is customary to burn or calcine the clay before use to remove the shrinkage, which otherwise is liable to cause a cracking of the bonding material, with which it is mixed for moulding. The flint clays stand rapid air-drying without cracking, but have to be slowly heated to prevent crazing or the formation of innumerable fine cracks. In refractoriness the flint clays usually stand in the lead. They are generally so very low in impurities of all kinds (including free silica) and their density is so high that they are very infusible at the highest temperatures attainable, except in electric furnaces, in spite of having a fine-grained structure. Most of them are not dangerously affected at temperatures as great as 2,700° F., for while incipient vitrification generally occurs at 2,300°, or an incipient white heat, flowage or yielding does not begin even when the intense, dazzling white heat of 2,700° is attained. They are therefore admirably adapted for refractory ware that has to withstand intense heats, as in glass, blast and open hearth steel furnaces. On account of their lack of strength, having no plasticity, they are better adapted for the dry heat of a furnace roof than exposure to abrasion.

JOINT STRUCTURE OF FLINT CLAY—LEASBURG.

CHEMICAL PROPERTIES.

The flint clays usually have four striking chemical characteristics: (1) a very high percentage of alumina, (2) a very high percentage of water, (3) a very low percentage of silica, and (4) a very low percentage of fluxing impurities. The first three are abnormal and are found in no other class of clays, but the fourth, or exceptional purity, is occasionally met with in fireclays and kaolins. The very high percentage of alumina and water and low percentage of silica seems to be due to a mixture of the two similar hydrous silicate of alumina minerals kaolinite and pholerite. The amount of alumina usually ranges from 37.0 to 43.0 per cent, averaging 40.0 per cent. The combined water ranges from 13.3 to 15.0 per cent, while the silica ranges from 40.4 to 48.0 per cent, with an average of 45.0 per cent. Placing this range in composition between the analyses of kaolinite and pholerite it is evident that flint clay is a variable mixture of these two very closely related minerals.

	Kaolinite.	Flint clay.	Pholerite.
Silica	46.3	(40.8 to 48.0) 45.8	39.3
Alumina	39.8	(37.0 to 43.0) 40.0	45.0
Water	13.9	(13.3 to 15.0) 14.2	15.7
Totals	100.0	100.0	100.0

The abnormal excess of alumina and water and deficient silica is noticed when compared with kaolinite. The large amount of water, which often exceeds 14.0 per cent, is the cause of the excessive fire-shrinkage, that is characteristic of the clay.

The fluxing constituents range from one, in the white to gray variety that is shipped to market as fireclay, to three per cent. When the deposit is contaminated by the red oxide of iron, and by lime the percentage rises often to 6.0 to 12.0 per cent. Of these impurities the iron is never absent, and fluctuates from 0.23 to 0.83 per cent, averageing in the light-colored variety 0.40, but when stained red or black, it increases to 3.0 to 13.0 per cent. The lime is unusually higher than than the iron, as might be expected in clay derived from the aluminous matter from the dissolution of limestones, and ranges from 0.3 to 2.0 per cent. The magnesia varies from a trace to 0.7 per cent. The alkalies (soda and potash) range from 0.2 to 1.2 per cent and average 0.6 per cent.

Occasionally flint clay is found of a very dark black color, the color being due to organic matter which burns out without injury to the clay. Such clays have been found to be too high in lime and iron

to be available for refractory purposes. In the flint clay as shipped to market, which is only taken from the central portion of the deposit, as the sandy mixture from the border is rejected, there is little or no free silica or sand, a fact which is very unusual and is not known in any other class of clays.

DETAILED OCCURRENCES OF FLINT CLAYS.

General Statement. The principal sources of the flint clay that is at present offered on the market are not numerous. The output of Warren and Montgomery counties on the Wabash railroad goes partly to St. Louis, but mainly to Chicago. That of Callaway county, on the Chicago and Alton railroad, is used by the fire-brick factories at Fulton and Mexico. That of Phelps, Crawford and Franklin counties along the St. Louis and San Francisco railroad is sent chiefly to St. Louis, though small amounts are shipped to the zinc smelters of southwestern Missouri and southeastern Kansas. The deposits in Gasconade, Osage and Morgan counties are too far from the railroad to bear the expense of shipment at present; which is also true of the deposits of St. Clair county.

Flint fireclay formerly brought \$2.00 to \$2.50 a ton on board the cars at the shipping points, but it has declined in recent years from excessive production to \$1.00, and occasional sales have been made during the recent depression as low as 80 cents. The latter prices are not commensurate with the exceptional purity of the clay and its high value as a "grog" in refractory ware, when it is considered that only exceptionally large pockets produce as much as 5,000 tons, usually less than 1,000 tons, of first-class, fine-grained light-colored clay.

Of the districts mentioned, Warren county has been a heavy shipper, mainly from Truesdale where the pockets are numerous. Rolla and St. James in Phelps county, Cuba and Leasburg in Crawford county, and Sullivan and St. Clair in Franklin county, are the shipping points of these districts. Very numerous deposits occur in the vicinity of Owensville in the southern part of Gasconade county, but the distance of 20 miles from the nearest railroad point renders them inaccessible at present. When the St. Louis, Kansas City and Colorado railroad is extended west from Union, as projected, it will bring these on the market. Numerous deposits occur about Linn, in Osage county; but a haul of eight to ten miles to reach the Missouri Pacific railroad prevents their being utilized. In Monroe county, near Stoutsville, are remnants of the true coal measure clays that frequently lack plasticity, but they do not belong to the true flint clay class of basin deposits.

The total output of the flint clay banks is estimated at 12,000 tons per annum, valued at $12,000; but it is very difficult to arrive at an accurate figure from the erratic production on a small scale of many banks.

WARREN COUNTY.

Warren county is one of the largest producers of flint clay in the state, and it ships to the St. Louis, Chicago, and Mexico, Mo., markets. Large shipments have been made from Truesdale and Pendleton, where all the banks thus far opened occur on the south side of the Wabash railroad, which in this county follows the divide between the drainage into the Missouri and Mississippi rivers. As the divide is a very gentle, sloping prairie of till or glacial drift, no flint clay has thus far been found until the breaks at the margin of the prairie are reached, which are from one to three miles distant. As the drift rapidly thins out towards the south the flint clay deposits are more frequently exposed by erosion on the south side of the railroad than on the north side, and for this reason prospecting has been much more successful on the south side. This has made such a deep impression on the clay-workers that the idea is prevalent that no flint clay occurs north of the line of the railroad. This is not true, however, and vigorous prospecting is liable to disclose fully as many prospects on the north side as on the south, though it requires more labor and expense to find them.

The flint fireclays occur from Foristell, in St. Charles county on the east, to High Hill in Montgomery county on the west, and from 1 to 6 miles north of the railroad and from 1 to 9 miles south of it. The banks have only begun to be worked, and many new ones will undoubtedly be discovered when the demand stimulates prospecting.

TRUESDALE.

The Truesdale district has proved very prolific in deposits of flint fireclay within a distance of 1 to 3 miles south of the Wabash. No workable deposits are known on the northern side of the railroad, and a popular prejudice prevails that none exist. While a thorough examination of the country north of Truesdale was not made there is little doubt that it will be found rich in clay deposits, as a single day's trip discovered several near Warrenton on the north side of the railroad, where this same prejudice prevails. The deposits thus far found south of Truesdale are in the rough, broken country, and invariably on side hills, where erosion has nearly removed the soil. They undoubtedly occur immediately around Truesdale, but as the country is a

flat prairie that is covered with a rather heavy mantle of drift, their discovery requires test pits which as yet have never been tried.

Big Kelly Pit. This pit is about one and one-fourth miles south of Truesdale, and was discovered in 1886. It was leased in 1888 and has been continuously operated with a total production to date of 6,000 tons, which is exceptionally large. A brown limestone of lower Carboniferous age outcrops 15 to 20 feet lower than the clay pit; and about 75 feet lower is a white to light gray, compact, sharp-grained sandstone that in places is locally indurated. This sandstone apparently rests on the Burlington limestone. The clay bank occurs at the head of a ravine, in which the above section is exposed. The pit is opened for a length of 150 feet in a northwesterly direction, and has a maximum width of 125 feet. A face of clean, pure flint clay is exposed for a width of 50 feet and a thickness of 20 feet. It is full of irregular joint planes, and has a light gray color. The eastern and southern sides of the pit expose coarse sandy fireclay, indicating the margin of the deposit in these directions, while sandy clay is also exposed at several places in the bottom. A plastic purple and yellow clay occurs in the west face, which seems to be a local pocket. The clay is worked by blasting at an expense of 12 to 15 cents a ton, and is hauled to the railroad station for 50 cents a ton, while the royalty amounts to 5 cents a ton. Most of the clay is shipped to St. Louis, 60 miles distant at an expense of 60 to 80 cents a ton for freight. Box cars are employed to prevent the clay falling into pieces when exposed to the weather.

A sample of the clay from the Big Kelley pit taken from the storage bins at the station showed the following characters: Color mostly white, to very light gray, with occasional irregular white spots one-twentieth to one-twelfth of an inch in size, somewhat superficially iron-stained on the joint planes. Texture massive, very hard (2.5 to 3.5), compact, with fracture conchoidal. Taste extremely lean. Slacks not at all. Pyrite was not visible. When ground to 20-mesh and mixed with 15.0 to 20.0 per cent of water it made an extremely short paste that shrunk 2.5 per cent in drying and 9.0 per cent when vitrified, giving a total shrinkage of 11.5 per cent. The air-dried mud had an average tensile strength of 13, with a maximum of 20 pounds to the square inch. It rapidly dried, but required to be slowly heated to avoid checking. Incipient vitrification occurred at 2,300° F., complete at 2,500°, viscous above 2,700°. It burned to a gray, compact, semi-vitrified body. Specific gravity, 2.39 to 2.45.

A TYPICAL FLINT CLAY DEPOSIT; KELLY PIT—TRUESDALE.

A chemical analysis gave:

	Per cent.
Silica	43.56
Alumina	41.48
Water	14.05
Iron sesquioxide	0.35
Lime	0.45
Magnesia	0.00
Alkalies	0.20
Total	100 09

New Kelly Pit. This bank lies about one and one-half miles south of Truesdale, and has produced about 1,500 tons since it was opened in 1893. It lies at the base of a hill composed of the white sub-crystalline, richly crinoidal Burlington limestone which surrounds the pit. The pit is opened 120 feet in a north and south line by 60 feet in width. A face of 15 feet of flint clay is exposed at the south end of the pit, and as the bottom is underlain by clays of excellent quality, the indications are that this will be a large producer. Part of the clay to a depth of 1 to 4 feet had weathered into a soft, plastic condition at the outcropping. This deposit shows horizontal stratification planes at the north end of the pit, which at the south end have a pitch of 5 to 12 degrees to the southwest. This is a very exceptional phenomenon in the flint clay deposits. The eastern side of the pit ends in a well defined slip having a smooth regular wall, with flint clay on the one side, and a mixture of chert bowlders in crushed and slickesided clay on the other side. The stripping which consists of soil and chert is very light, varying from 1 to 6 feet, and averages 2 feet. The flint clay is light gray, very hard, and compact, except when weathered at the outcrop as mentioned. There is an eminently developed joint structure, and exposure tends to develop spherical weathering.

Little Kelly Pit. The Little Kelly pit is also one and one-half miles south of Truesdale on the Fahnmeyer land. It occurs on the eastern slope of a side hill. The face exposed is 12 feet thick and 35 feet long, and shows an excellent quality of flint clay. It has become sandy and red at the south end, indicating its termination in this direction. The stripping of soil and chert over the flint clay varies from 1 to 3 feet.

Neighboring Pits. About 100 yards southeast of the Big Kelly pit are two small test pits that disclose flint clay. Two hundred yards to the north is a small deposit of flint clay that was opened in 1891. A face of 20 feet wide by 10 feet deep of coarse sandy flint clay was opened for some distance, but no further work was done, on account of the unsatisfactory quality. The flint clay is everlain by only a few inches of soil and chert. Three hundred yards northwest of Big

Kelly pit is a small pit of flint clay which shows a face of 15 feet in depth by 40 feet long. This was driven into for a distance of 35 feet. Five hundred tons were shipped. The clay is partly good clean flint clay, but partly coarse and sandy. Slight stratification is apparent, which corresponds to the slope of the hillside, or dips about 10 degrees to the north. The flint clay is capped by 1 to 3 feet of soil and chert.

Hammel Pit. One and one-fourth miles southeast of Truesdale on the bank of Charette creek, a flint clay of excellent quality occurs on the Hammel land. The face exposed is 12 feet thick by 20 feet wide, and is opened into for a distance of 20 feet. The clay was coarse and sandy in the beginning, being evidently on the edge of the pocket, but has since changed into a uniform fine-grained pure clay. The shipments thus far only amount to about 50 tons.

Minor Pits. About two and one-fourth miles southeast of Truesdale are several small pits of clay on the Meyer land. One hundred yards south of the Little Kelly pit is a small exhausted excavation on the Dixon land, which was worked in 1884, while a test pit 100 yards southwest discloses an impure flint clay. Two hundred yards southwest of the Little Kelly is a small pit showing a sandy flint clay, and a short distance southeast are two small pits that have just been opened, while adjoining is an old pit that was worked in 1884. The last pit has a diameter of about 100 feet and a depth of 20 feet. This group of pits is surrounded by the Burlington limestone which is here a tough, compact, light brown sub-crystalline rock that is full of crinoid fragments.

Mexico Pit. Two miles southeast of Truesdale (T. 47 N., R. II W., Sec. 34, SW. qr.) are two pits of flint clay that are operated by the Mexico Fire Brick Co. of Mexico, Mo. The old pit was worked in 1880-81 when about 1,500 tons were shipped. Since that time no work was done until 1891, in which year 1,800 tons were shipped and about 200 tons in the year following, when the factory was destroyed by fire. This pit was about 100 feet in diameter and 18 feet in depth and was worked to the usual sandstone margins at the sides and bottom.

The new pit, which is 100 feet south of the old one, it 70 feet in diameter and 14 feet deep. Since it was opened in August, 1891, over 1,900 tons have been shipped. A heavy body of red or iron-stained flint clay crops out along the east face which is not worked. A calciner has been erected to reduce the freight by expelling the water before shipping; it is a cupola or stack furnace that is 5 feet in diameter and 12 feet high. It is said to have a capacity of 20 tons in 24 hours and to require about 300 pounds of Mount Olive coal for each ton of clay. The clay was shipped to the firebrick works at Mexico for mak-

ing the higher grades of firebrick and for a "grog." Outcrops of flint clay occur 50 to 200 yards east of the pit, indicating that there are other bodies in the immediate vicinity.

Pierce Pit. This pit was opened in 1880, and produced about 2,000 tons. It was oval in shape, with a length of 75 feet, a width of 50 feet and a maximum depth of 15 feet. It was worked to the sandy clays and sandstone on the sides and bottom, and is therefore exhausted.

Linneback Pit. About three miles southeast of Truesdale (Tp. 47 N., R. II W., Sec. 25, SW. qr.) on the Linneback land, is a pit which was opened in 1886 and which produced about 4,000 tons of flint clay. The pit is near the top of the high bluff of Charette creek, the lower portion of which consists of the white to ferruginous Burlington limestone. It is about 100 feet in diameter with a depth of 30 feet. It is nearly exhausted as the sandy clay is exposed on three sides as shown in the annexed cut (figure 10). The clay was partly calcined in order to reduce the freight, and was sold in the St. Louis and Chicago markets.

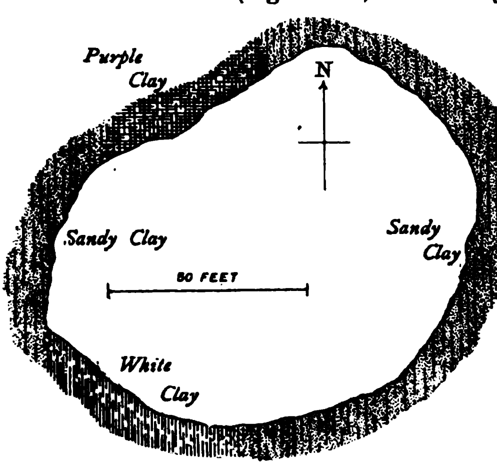


Figure 10. Plan of Linneback Flint Clay Pit.

WARRENTON.

Numerous prospects of flint clay are found north of Warrenton, but as yet they are not worked, though of excellent quality, on account of the distance from the railroad. Sufficient work has not been done to disclose their size, but there is every probability of their being similar to the Truesdale clays, in quality and magnitude and to have a producing capacity of 500 to 4,000 tons of clay for each bank before exhaustion. Thorough prospecting would disclose many others, as this district is rich in these valuable deposits. This is evident from the geology of the place, and the prospects described below were the result of one day's trip to disprove a popular prejudice that the flint clays did not occur north of the railroad line.

On the Truxton road, three and one-half miles north of Warrenton and about 500 feet north of the Pendleton branch of Big creek, a gray flint clay crops out along the road for a depth of about 5 feet. It merges into a ferruginous or red flint clay, which latter has more or less completely weathered into a plastic clay. Portions of the latter carry

nuggets and fragments of argillaceous red hematite or iron ore. In the creek bottom at the foot of the hill the Burlington limestone is exposed 10 feet below the clay outcrop.

On Bekermeyer farm, 800 feet southwest of the above mentioned exposure, flint clay is exposed for 75 feet along a small branch under a capping of 2 feet of soil and gravel. It is mostly coarse sandy clay and is largely stained red. In runs into sandstone at the east end of the exposure and into a gray plastic clay at the west. Three hundred feet east, or down the branch, the bank of the creek consists largely of chert with the interstices filled with plastic gray clay for about 50 feet, indicating the immediate proximity of a flint clay bank. At another spot 300 feet northwest of the above on the opposite face of the hill a plastic gray clay shows in the bank of a small rivulet which again indicates the proximity of a flint clay deposit.

On the Kemper land (Tp. 47 N., R. II W., Sec. 8, NE. qr.) about three miles north of Warrenton, flint clay is exposed in the bank of a branch of Big creek, about 200 feet from its junction with the latter. Only one foot outcrops in the creek, and it is surrounded by the Burlington limestone, which rises from 50 to 75 feet above the creek level. On the portion of the Kemper estate leased by Jno. Davis, about three and one half miles north of Warrenton, flint fireclay is exposed in the bank of a small creek. It is associated with a coarse sandy clay, and also some red flint clay or "keel." The Burlington limestone outcrops in the creek bed 5 feet lower than the outcrop of mixed clay.

On the Keyes farm, about five miles north of Warrenton, flint clay outcrops on the bank of a small branch. There seems to be a deposit of at least 75 feet in length, as exposed by the creek and over 4 feet in thickness at the creek level. One hundred yards north of the above, on a very small branch, blue and gray fireclay is exposed for over 100 feet. It appears to be over 10 feet in thickness.

On the Hollmann place (T. 47 N., R. II W., Sec. 5) flint fireclay crops out on a small tongue between two dry branches. The outcroppings are exposed for over 25 feet in a north and south direction. The clay is of excellent quality. The Burlington limestone is exposed in the creek bed on each side of the flint clay outcrop.

On the Hawk Point road, five miles north of the town, near the top of the hill south of the bridge on the Pendleton branch of Big creek, flint clay is exposed on each side of the road. About 2 feet are visible.

PENDLETON.

Chiles Pits. Two and one-half miles southwest of Pendleton (T. 47 N., R. III W., Sec. 28) are a series of flint clay banks that are operated by the Chiles brothers of Pendleton. They were opened in 1890 and have produced over 4,000 tons. The clay is all sent to Chicago where it is sold for $3.00, of which $2.00 represents freight. This clay has mainly come from the big pit B (figure 11) in which there is a face exposed that is 20 feet high and 75 feet long. It is mostly a bluish gray clay that is considerably speckled with white spots and is somewhat sandy at one end of the pit. It is overlain by 6 to 12 inches of soil and gravel. It lies near the top of the west bank of West Lost creek, between which outcrops brown limestone probably of Burlington age. Around the big Chiles pit are several smaller pits, as shown in the sketch. A sample of the clay gave the following results: Color light to dark gray, with occasional dark brown to black iron stains. Texture massive, compact, very hard (2.5 to 3.0), fine- to coarse-grained, breaking with a conchoidal fracture. Taste extremely lean. Slacked slowly and imperfectly into coarse granules one-tenth to one-twelfth of an inch in size. Pyrite was not noticeable. When ground to 20-mesh and mixed with 15.0 per cent of water it made a very lean paste that shrunk 3.0 per cent in drying and 9.0 per cent when vitrified, giving a total shrinkage of 12.0 per cent. The air-dried mud had an average tensile strength of 24, and a maximum of 27 pounds to the square inch. Incipient vitrification occurred at 2,300° F., complete at 2,500°, and viscous above 2,700°. The clay dried rapidly, but required slow heating and cooling to avoid checking. It burned to a gray, compact, somewhat tough body when vitrified. Specific gravity 2.42.

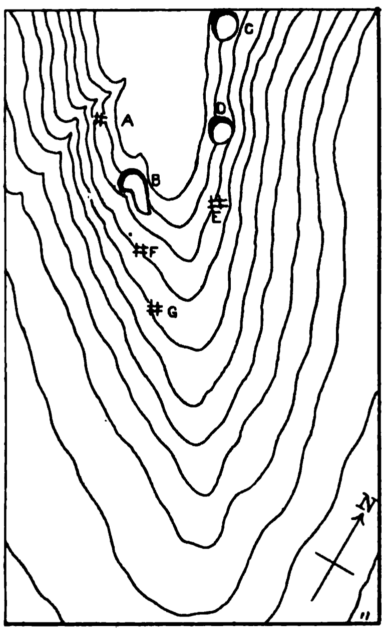


Figure 11. Plan of Chiles Flint Clay Pits.

A chemical analysis gave the following results:

	Per cent.
Silica	46.18
Alumina	38.12
Water	14.01
Iron sesquioxide	0.32
Lime	0.54
Magnesia	trace.
Alkalies	1.20
Total	100.37

At pit A (see sketch) the flint clay crops out on the surface near the crest of the hill, while 50 feet north there is an outcrop of sandstone. Pit C is on the crest of the hill and is a small pit 30 feet wide, 10 feet deep and 25 feet long. It produced about 100 tons, but the clay became too sandy to use. Pit D is very small, one from which 25 tons were shipped. The clay in this pit is partly light gray, partly bluish and partly purplish colored from iron-staining. At E and F the flint fireclay outcrops on the surface.

Flint fireclay is also said to occur three and one-half miles south of Pendleton, but the haul is too long to enable the clay to be profitably worked.

MONTGOMERY COUNTY.

Flint fireclay occurs in the eastern part of the county and is extensively shipped from High Hill. It is likely to be found throughout the county, but at present no deposits are known in the western part.

HIGH HILL.

Big Miller Pit. About one and one-half miles southwest of High Hill (T. 47 N., R. IV W., Sec. 6, NE. qr.) is a large pit that is leased by L. P. Miller. The bank is on the flank of a hill, along which the workings extend 100 feet, with a width of 85 feet. The pit was opened in 1871. It is not worked regularly, though the total production to date amounts to about 2,500 tons. The flint clay is overlain by 1 to 4 feet of yellow clay and chert. It costs 8 cents a ton for blasting, 50 cents a ton for hauling to the station, and 5 cents royalty, while the price realized on board cars is 85 cents to $1.00 a ton.

A sample of the clay collected gave the following results: Color very light gray, almost white, with occasional yellow to brown iron stains, or black manganese stains. Texture very fine-grained, uniform, compact, massive, very hard (3.0 to 3.5). Fracture conchoidal. Slacked very slightly. Pyrite was not noticeable. When ground to 20-mesh and mixed with 17.0 per cent water it made a very lean paste that shrunk 3.5 per cent in drying and 10.0 per cent when vitrified, giving a total shrinkage of 13.5 per cent. The air-dried mud had an

average tensile strength of 14, and a maximum of 18 pounds to the square inch. Incipient vitrification occurred at 2,300° F., complete at 2,550°, viscous above 2,700°. The clay burned to a light gray body with moderate strength. Specific gravity, 2.33.

A chemical analysis gave the following results:

	Per cent.
Silica	45.12
Alumina	40.46
Water	13.34
Iron sesquioxide	0.47
Lime	0.29
Magnesia	trace
Alkalies	0.30
Total	99.98

Hans Miller Pit. One hundred yards west of the Big Miller pit at the foot of a hill is a pit 60 feet wide by 70 feet long. The stripping of yellow clay is from 1 to 3 feet. A tough brown, sub-crystalline limestone is exposed in the bed of the creek immediately below the clay bank.

Chicago Pit. In the SE. ¼ of the NW. qr. of Sec. 5, Tp. 47 N., R. IV W., are two abandoned pits on a small dry branch. They belong to the Chicago Retort and Firebrick Co. The clay has been worked out to the sandstone fringe, and about 2,000 tons are said to have been produced up to 1891.

Little Miller Pit. Adjoining those of the Chicago company are several which were opened in 1875. They produced about 1,000 tons of clay before exhaustion.

Capstix Pit is in the SW. ¼ of the SE qr. of Sec. 5, Tp. 47 N., R. IV W. It was opened in 1881 by Mr. Miller and has produced about 2,500 tons.

CALLAWAY COUNTY.

Callaway county contains some flint fireclay that has thus far been utilized to only a limited extent. The deposits are very important because of a transition that takes place between the usual type of plastic fireclay and the abnormal, hard, and non-plastic flint clay. A complete graduation is observed. The normal-stratified fireclay found under workable coal seams, over the lower Carboniferous limestone pass through a less plastic but still normal type of fireclay that is usually on the limestone, to the hard, non-plastic, usually non-stratified typical flint fireclay. This county presents evidence leaving little doubt that flint fireclay, like plastic fireclay, was at least primarily of sedimentary origin, though subsequently the flint clay was altered by chemical action.

The plastic fireclay from the mine of the Fulton Fireclay Co. is also very pure, having only 2.55 per cent of impurities, or less than 1.0 per cent higher than most of the clays. The analysis is given below, together with that of a typical flint clay (Pendleton) for comparison:

	PLASTIC CLAY *(Fulton)*. Per cent.	FLINT CLAY *(Pendleton)*. Per cent.
Silica	47.30	46.18
Alumina	37 54	38 12
Water	12.76	14.01
Iron sesquioxide	1.48	0 32
Lime	0.57	0 54
Magnesia	0 00	trace
Alkalies	0 50	1.20
Total	100.15	100.37

The specific gravity of the first is 2.44, and of the second 2.42. The analysis of the Fulton clay shows that chemically this clay is not only very pure, but closely resembles the flint clays in the high percentage of alumina and water, while the specific gravity is but a trifle higher.

Fulton. About one half mile northeast of the court house, on the Smith land (T. 47 N., R. IX W., Sec. 9, SW. qr.) a hard flint fireclay crops out for 150 feet along the side of the St. Charles road. It rests on an irregular sandstone that appears to be local. It is stated that it is 8 to 10 feet in thickness, but that it is only a pocket, as is characteristic of this class of deposits. It is a light gray, coarse-grained, flint clay of seemingly excellent quality. It was tried at the Mexico Firebrick works and found to be highly refractory. Another pocket of flint clay exists on the Threlkeld property about 3 miles northeast of Fulton. A third deposit of considerable size occurs in the bed of Stimson creek about one-half mile southwest of Fulton. It is about 20 feet thick in the middle and about 400 feet long in an east and west direction. It rests on sandstone and feathers out at the edges. Most of it is plastic, but occasionally hard spots indicate that formerly it was all flint clay. The bed of the creek once flowed over it in the wet season, which perhaps accounts for the softening action extending to such a depth. It was used in the firebrick works where it proved eminently satisfactory. This pocket occupies a basin in the top of the lower Carboniferous limestone and the coal measures adjoin it on the south and west. It thus seems to be a local thickening of the true coal measure fireclay, which settled in and completely filled this former sink-hole in the limestone, as a flint clay deposit. On the Owen land (T. 47 N., R. IX W., Sec. 22, NW. qr.) is a bed of flint clay 4 feet thick.

BOONE COUNTY.

Flint clay exists in this district and possibly to a considerable extent, but thus far it has not been utilized. The areas in which it is likely to be found are the central and southern portions, or from Columbia southward beyond the edge of the coal measures. The absence of a demand has not stimulated prospecting, which under such an incentive might result in the discovery of extensive deposits.

Columbia. One and one-half miles east, on the east bank of Hominy creek, flint fireclay outcrops along the Fulton road. There are 12 feet of clay in sight, with a possibility of a much greater thickness. It rests on a conglomerate that immediately overlies the lower carboniferous limestone. Part of the clay is weathered to a plastic condition and occasionally it is stained by iron.

MONROE COUNTY.

Monroe county is similar to Callaway in having a few known pockets of flint fireclays that are at or beyond the margin of the coal measures. They have not been utilized as yet, and it remains to be proved whether they are very numerous.

Stoutsville. About one and one-fourth miles west of the station in a cut on the Missouri, Kansas and Texas railroad a dark gray flint fireclay is exposed, but no work has been done to develop it or determine its size or value. The Burlington limestone crops out 15 feet higher.

Clapper. Three miles west of Clapper near the Dannenhauer and Winder pottery and on the Williamson land (T. 56 N., R. IX W., Sec. 34, SW. qr.) is a deposit of fireclay that is a transition between the flint and plastic clays, as it contains both in the same bed, similar to the Fulton clay (Stimson creek). It is a remnant of the basal fireclay seam of the lower coal measures, which formation thins out in this district (being only found on the hill tops), so that it is not similar in origin or structure to the basin flint clay deposits of the limestone areas. The lower part of the bed is practically non-plastic. It would be graded as flint clay by the trade, though in its shrinking properties, bedded structure and high percentage of silica (from abundant sand) it differs greatly from the normal Missouri flint clay. The deposit occurs near the crest of a gentle hill, flanking a small creek along which it is exposed for over 500 feet. The workings are limited as they only expose a width of 75 feet, after being worked on a small scale for 40 years for small local potteries. The clay occurs as a seam of 4 to 7 feet in thickness, under 1 to 5 feet of soil, and is underlain by sandstone. The lower portion of the seam is very coarse-grained, sandy,

hard, and but very slightly plastic, and is the most refractory clay known from this state. The upper portion of the seam is fine-grained, sandy, more or less soft, and decidedly plastic; it is very much less refractory (by 300° F.) than the coarse clay and is used by the stoneware potteries, while the other is not utilized. The two kinds were sampled, and on testing gave the following results: The upper portion in color was light gray (dry) with slight red to yellow iron stains. Texture massive, compact, hard (2.0 to 2.5), fine-grained, with abundant coarse sand. Taste fat and very sandy. Slacked readily and completely to one-tenth to one-fortieth of an inch granules. Pyrite was not noticeable. It burned to a white to gray, compact, very tough, vitrified body, and rapidly dried and heated without cracking. It is well adapted for refractory ware and stoneware.

The lower part in color was light gray (dry), with yellow iron stains. Texture massive, compact, hard (2.0 to 2.5), coarse-grained, with abundant coarse sand. Taste very lean and sandy. Slacked not at all. Pyrite was not noticeable. It burned to a white to gray, compact, rather strong body, but did not vitrify. It dried rapidly and heated without cracking. It is admirably adapted for the severest uses of refractory ware, as it possesses an unusually high degree of refractoriness.

The other physical and chemical properties of the two are given below side by side to show their almost identical composition and density, but very different plasticity, shrinkage, and fusibility. These tables very sharply bring out the great importance of the fineness of grain in affecting the fusibility. For the more fusible one of the two, or the plastic sample, has 0.49 per cent less fluxing impurities than the coarse non-plastic sample, yet it is more fusible by at least 300° F.

Physical Analyses of Clapper Clays.

	Plastic.	Slightly Plastic.
Water required for paste	15.5 per cent.	14.0 per cent.
Tensile strength, average	92 pounds.	83 pounds.
Tensile strength, maximum	109 pounds.	89 pounds.
Shrinkage, in dr. ing	5.0 per cent.	3.0 per cent.
Shrinkage, in burning	5.2 per cent.	1.5 per cent.
Shrinkage, total	10 2 per cent	5.3 per cent.
Temperature, incipient vitrification	2,200 degrees F.	2,500 degrees F.
Complete vitrification	2,400 "	2,650 "
Viscous, above	2,600 "	2,700 "
Specific gravity	2 43 "	2.45 "

Chemical Composition of Clapper Clays.

	Plastic.	Slightly Plastic.
Silica	70.80	67.76
Alumina	20.85	21.96
Water, combined	7.12	7.80
Moisture	0.79	0.43
Iron sesquioxide	0.15	0.69
Lime	0.67	0.96
Magnesia	0.38	0.24
Alkalies	0.49	0.24
Total	100.20	100.08
Total fluxers	1.64	2.13

ST. LOUIS COUNTY.

In the western portion of St. Louis county, from Valley Park westward, flint clays are liable to occur in the Ordovician limestones. Several deposits have been found in the neighborhood of Glencoe, though they are so contaminated by iron as to be dark red in color and valueless for refractory purposes. Samples of plastic, light gray clay from this county strongly indicated that they were from the weathered outcrop of flint clay banks. The western portion of the county is highly favorable for the occurrence of these flint fireclays, especially over the pure Trenton limestone areas (see map of St. Louis county), and energetic intelligent prospecting would undoubtedly be rewarded.

GLENCOE.

Doyle Bank. Four miles northwest of Glencoe station, on the Missouri Pacific railroad, about one mile northwest of the upper Glencoe lime kilns, there are several croppings of flint clay on the Funk place, on the south side of the Manchester road near the 27th mile post. It crops out in several places along the ravine, and seems to be from 10 to 30 feet in thickness. The clay has not been worked and much of it is stained dark red by iron, though considerable of it is a light gray and not thus contaminated. From 1 to 2 feet of sandstone are associated with the clay, which probably is the underlying fringe of the clay pocket. The nearest railroad switch is at the upper Glencoe lime kilns, about one mile distant, with an intervening down grade.

Stossberg Bank. A short distance northwest of the Doyle bank a mixed gray and red flint clay crops out along the hillside in several places, on the Stossberg land, on the south of the Manchester road.

ALLENTON.

One and one-half miles north of the station on the Paule land, red flint clay was struck in sinking a well, which while of little or no value in itself, indicates the very probable presence of gray or non-ferruginous flint clay.

FRANKLIN COUNTY.

Franklin county is very rich in deposits of flint fireclay. They occur throughout the entire district and are worked near Washington and Union. Large shipments have been made from Dry Branch (or Anaconda) and Stanton. While shipments have been confined to but few points, the low prices prevailing for this class of clay has not stimulated or encouraged prospecting and only such deposits as are situated in the immediate neighborhood of the railroad can be operated with even a meager profit.

WASHINGTON.

Grinker Pit. West of Washington one and one-half miles, and 500 yards north of the pottery, along the crest of the ridge, is an old flint clay bank. It consists of a mixture of red, gray and black flint clay, most of the face that is at present exposed being very dark drab, running into red, with a minor amount of gray. The clay is more or less weathered and thereby rendered somewhat plastic, so that it has been used at the Washington potteries. The pit is about 200 feet long in an east and west direction, and 30 to 60 feet wide, with a depth of 3 to 10 feet to the pond which fills the bottom of the pit. The clay is overlain by 6 to 24 inches of soil and gravel.

UNION.

Maune Pit. Four miles north and about 200 yards west of the Washington rock road (T. 43 N., R. I W., Sec. 16, W. hf.) on the Maune land is an extensive deposit of flint clay. In 1889 three shafts were sunk about 100 feet apart in a north and south line in search of coal and lead. The central one is over 50 feet deep and on its dump are both fine and coarse grained gray flint clays. The north and south shafts show ferruginous red clay, and seem to reach the underlying sandstone. They are on the edge of a high hill crest, and indicate a deposit of exceptional magnitude but insufficient work has been done to disclose the extent and character of the deposit.

Berghorn Pit. One-half mile north of Union, on the Berghorn place there is said to occur 7 to 8 feet of good clay.

Buck and Whitson Pit. This bank is described under the bond clays, as the outcrop has weathered for several feet to a plastic clay.

ANACONDA.

Fisher Clay Bank. One-half mile east of the St. Louis and San Francisco railroad station (Tp. 41 N., R. I W., Sec. 16, NE. qr.) is a pocket of flint fireclay that has been worked by the Fisher brothers of Dry Branch (Anaconda, since 1892). This pit is on the crest of a gently sloping hill, and was discovered in prospecting for iron in 1890. It is claimed to have produced 700 cars or about 14,000 tons, but this is probably greatly exaggerated. The clay has been shipped to St. Louis and Chicago, and is sold for $1.00 a ton on board cars at Anaconda, with a freight rate to St. Louis a distance of 57 miles, of $12.00 a car. The pit has been worked to the sandstone margin as shown in the sketch (figure 12). On three sides is a coarse-grained white to

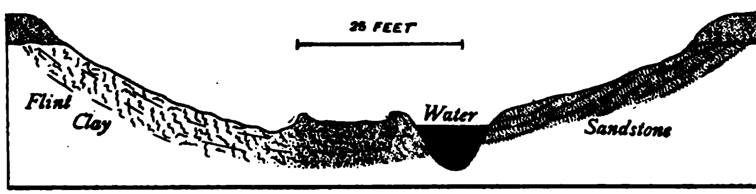


Figure 12. Section of Fisher Flint Clay Pit.

yellow sandstone that dips at 60 to 70 degrees into the pit at the north end, and at 35 to 40 degrees on the west side. The fireclay is light gray except near the sandstone, where it is sometimes stained red by iron. It is very hard, compact, breaks with a conchoidal fracture, and weathers into spherical masses. It is mostly very fine-grained except in the center of the pit, where it is so coarse and sandy that it is not shipped. The upper 2 to 3 feet have weathered into a plastic clay which rapidly merges into the hard, non-plastic portion. The average depth of the pit is 15 to 18 feet, varying from 7 to 20 feet to the water level, below which it is said to extend several feet. A little fireclay remains on the southeast side of the pit, but otherwise it is exhausted to the sandstone walls. The fireclay runs into the irregularities, joints and seams of the sandstone.

The physical characters of this clay are as follows: Color uniform, light gray, with yellow to brown iron stains. Texture massive, hard (2.5 to 2.8), compact, uniform and very fine-grained. Fracture conchoidal. Taste very lean. Did not slack. Pyrite was not noticeable. When ground to 20-mesh and mixed with 15.5 per cent of water it made an extremely lean paste that shrunk 3.2 per cent on drying and 9.6 per cent when vitrified, giving a total shrinkage of 12.8 per cent. The air-dried mud had an average tensile strength of 14, and a maximum

of 15 pounds to the square inch. Incipient vitrification occurred at 2,300° F., complete at 2,500°, and viscous above 2,700°. It burned to a white compact, rather strong body that dried rapidly, but needed slow burning to avoid checking. Specific gravity 2.43.

A chemical analysis gave the following results:

	Per cent.
Silica	42.60
Alumina	41.88
Water	14.00
Iron sesquioxide	0.62
Lime	0.28
Magnesia	0.20
Alkalies	0.54
Total	100.12

Peterson Banks. A short distance northwest of Anaconda (Tp. 41 N., R. I. W., Sec. 8, SW. qr.) and 125 yards south of the Springfield state road is the Peterson bank. It occurs in a gently sloping pasture in an easy rolling sandstone country, and was found in 1889 in digging reservoirs. Sixty cars or 1,200 tons were shipped in 1890, since which time it has been leased on a royalty of 10 cents a ton. The pit is elliptical in shape and about 40 by 80 feet in size. The flint clay is overlain by 3 feet of chert gravel, over which are two feet of soil. No sandstone has been met with as yet, and from the evidence of adjoining test pits this basin is 200 to 250 feet in diameter.

About 1,000 feet to the southwest is the new Peterson bank. It was opened in November, 1892, and a face 25 feet long by 8 feet deep has been carried on for 50 feet. The clay shows on all sides and is overlain by gravel. The upper one foot of the flint clay is soft and plastic, below which it is very hard, compact, massive, and with an eminently conchoidal fracture. It is light gray in color, with slight red iron stains along the edges. The clay shows a slight bedded structure, with a dip of 3 to 10 degrees to the east. It occurs in a coarse yellow to white sandstone formation, at the bottom of a gentle hollow, and was exposed by the erosion of a creek that cuts through one side of it. Mr. Peterson has found gray, plastic clay in plowing the field between these pits, which almost conclusively shows the presence of another pocket.

Hibbard Bank. About two miles southeast of Anaconda (Tp. 41 N., R. I W., Sec. 22, NW. qr.) on the Reed land is a pit of flint clay from which were shipped about 200 tons in 1892. The clay is mainly red to purple-colored, with only a little that is light gray.

Johnson Bank. North of Anaconda one and one-half miles (Tp. 41 N., R. I W., Sec. 9, SW. qr.) is the clay bank of Richard Johnson. The outcrop is along a wooded ravine. The pit has produced about

100 tons of flint clay. Part of the clay is contaminated with iron, being dark red in color.

STANTON.

Flint clay occurs south of Stanton, within one to three miles of the railroad, and some is shipped to St. Louis.

Reupple Pit. In section 25 (Tp. 41 N., R. II W.) is a light gray, medium to coarse-grained, somewhat sandy flint fireclay.

SULLIVAN.

In digging a cistern for the elevator near the railroad station at Sullivan, in 1892, a mixture of sandstone, flint clay and chert was struck under 3 to 4 feet of soil and chert gravel, which while not workable from excessive chert and sandstone, indicates the probable presence of a purer body of flint clay. The fireclay is plastic, as is usually the case, when mined so near the surface in such an open porous mixture.

About one mile southeast of the town on the Blair farm, on the west side of Spring creek mill road, 7 feet of a similar mixture of fireclay, chert and sandstone occur at a depth of 5 feet. The fireclay is soft and plastic for 1 to 2 feet, and then merges into the hard, nonplastic clay. The deposit is mainly chert for the upper 4 feet, but chiefly flint clay for the lower 3 feet, and the bottom of the pit is still in flint clay. The quality of the clay is excellent except for its contamination with chert. Mr. Blair states that the clay occurs at a point 200 yards distant, near the roadside, but this is now obscured by wash.

On the Speer farm, about 6 miles west of Sullivan, 6 feet of flint fireclay are said to have been found in building a cistern. The clay is said to have been free from impurities, and the bottom of the cistern was still in the solid body of clay.

CRAWFORD COUNTY.

Crawford county is one of the largest producers of flint clay in the state. Extensive shipments have been made since 1879. There are undoubtedly many other undiscovered deposits near the railroad that passes through its northwestern corner. It is also very probable that they occur more or less frequently throughout the entire county.

BOURBON.

Flint clay banks are opened four miles north of Bourbon, also four miles west on the Eldridge farm and on the Monroe land, but no shipments are being made at the present time.

LEASBURG.

Rowden Bank. About one-half mile north of Leasburg (Tp. 39 N., R. IV W., Sec. 13) is a flint clay bank that was opened in May, 1893. A view of the pit when work first began is shown in plate IX. It is typical of a large number of these openings. The surface exposed is 20 feet long, 15 feet wide and 10 feet high. It shows a very fine-grained, uniform, light gray flint fireclay. The clay is more or less stained yellow along the joint planes by iron. It is overlain by two feet of soil and gravel, and the top of the clay is weathered for a distance of 1 to 4 feet. The mining costs 25 cents a ton, the clay being blasted with powder; the hauling 40 cents; and the royalty 5 cents; while it sells for $1.00 on board the cars, or $1.75 a ton free on board cars in St. Louis, freight being $16.00 a car. There is another pocket of flint clay in the southeast quarter of section 13, but it has not been developed.

Ellison Pit is two and one-half miles northwest of Leasburg. It is 20 feet long, 20 feet wide, and 5 to 15 feet deep, and the clay is overlain by 1 to 3 feet of soil and chert. Some of the clay is fine-grained and light gray in color, but much of it is coarse and sandy, or else stained red with iron.

Osborne Banks. These are in the northwest quarter of the southeast quarter of section 13 (Tp. 39 N., R. IV W.) One of the pits was opened about 1883, and produced about 5,000 tons. It is a circular pit being about 150 feet in diameter, and about 20 feet deep. Red or iron-stained flint clay at present fringes the sides except on the east, where a little good light gray clay still remains.

A small pit occurs about 300 feet southwest of the preceding one, that is about 40 feet long, 10 to 20 feet wide and 5 to 10 feet deep.

Moore Bank. The location of this pit is two miles southwest of Leasburg, on the flank of a sandstone hill. It was opened in February, 1888, and produced about 400 tons, up to 1893. The fireclay partially outcrops, but the greater portion is covered by 1 to 3 feet of soil and chert gravel. The pit is about 40 feet in diameter and 10 feet in depth. The basal sandstone is reached on the west face, where it dips at about 30 degrees toward the center, while on the south side is a very sandy clay, indicating the exhaustion of the pit in that direction. A mottled clay is exposed on the surface and an excellent fine-grained, gray flint clay shows on the north face.

About one-fourth mile east of the above pit is another flint clay prospect.

ROWDEN FLINT CLAY BANK—LEASBURG.

George Moore Pit. One mile west of Leasburg, and about 200 yards south of the St. Louis and San Francisco railroad is a flint fireclay on the land of Geo. W. Moore. The pit was opened about 1883, and was operated during the two subsequent years, producing about 1,500 tons, since which time it has been idle. The pit lies near the top of the hill, in a rough sandstone district, and is about 60 feet long, 20 feet wide and 20 to 25 feet deep. The sandstone is exposed on the east face, dipping towards the center of the pit at angles of 30 to 60 degrees. Mixed red flint clay and sandstone are exposed at the south face, which dips at 30 degrees into the pit. Red or ferruginous flint clay is exposed on the north face and a light gray, uniform, fine-grained, excellent quality of flint clay on the west face.

McClintick Bank. The first pit opened in Leasburg was in 1879, on the Carlisle land, which was leased by Geo. L. McClintick. Some of the clay from the bank was shipped as far east as Pittsburg. Thirty-one cars of clay were produced in 1888, 43 cars in 1889, 29 cars in 1890, and 16 cars in 1891, making a total of 119 cars, or 2,380 tons in four years.

McWilliams Pit. Two miles north of the town on the McWilliams land is a flint fireclay bank that produced 500 tons in 1890.

Wall Bank is about one mile northwest of Leasburg on the land of Wallace Wall. The production of flint fireclay was 1,500 tons in 1885.

Humphreys Bank. About one and one-fourth miles southwest of Leasburg is the Humphrey bank, from which was shipped about 1,800 tons in 1884.

A sample of flint fireclay from Leasburg gave the following results: Color very light gray, with slight brown iron stains. Texture massive, uniform, compact, hard (2.5 to 3.0), very fine-grained. Fracture, conchoidal. Taste, lean. Slacked not at all. Pyrite was not noticeable. When ground to 20-mesh and mixed with 15.0 per cent of water it made an extremely lean paste that shrunk 3.1 per cent in drying and 11.6 per cent when vitrified, giving a total shrinkage of 14.7 per cent. The air-dried mud had an average tensile strength of 8 and a maximum strength of ten pounds to the square inch. Incipient vitrification occurred at 2,300° F., complete at 2,500° and viscous over 2,700°. It dried rapidly, but needed to be burned slowly to avoid checking. It is a superior clay for grog, after calcination, to reduce the shrinkage. Specific gravity 2.35.

A chemical analysis gave:

	Per cent.
Silica	43.82
Alumina	38 24
Water	14.94
Iron sesquioxide	0.23
Lime	1.93
Magnesia	trace
Alkalies	0.73
Total	99.89

CUBA.

In the vicinity of Cuba there are a number of deposits of flint fireclay. Of those examined the most important are the following: on the McCormick place one and one-half miles east of the town, on the Kemp land two miles east, on the Fitzpatrick place one mile west of Cuba, where three small test pits disclose an excellent grade of light gray fireclay and also flint fireclays; on the Creek farm four miles northwest, and on the Feen place four miles north of Cuba.

SLIGO FURNACE.

About three miles northwest of Sligo furnace (Tp. 36 N., R. I W., Sec. 31) is a bank of flint clay that was discovered by William Sankey. It crops out on the hillside and a pit reached a depth of 7 feet. It is a very light gray, non-plastic clay. No shipments have been made from it.

HIGHWAY STATION.

Two and one-half miles south, on the St. Louis, Salem and Little Rock railroad, in section 2 (T. 36 N., R. IV W.), flint fireclay occurs on the land of Robert Kelly.

PHELPS COUNTY.

Phelps county is rich in flint fireclay deposits. They have been extensively worked at St. James and to a less extent at Knobview and Rolla. As the flint fireclays occur in Maries county on the north, as well as in Crawford on the east, it is highly probable that they exist throughout the entire county, or at least over the greater portion of it. As the divide followed by the St. Louis and San Francisco railroad through this county is very even, outcrops will not occur close to the railroad, and test pits will be necessary in prospecting.

KNOBVIEW.

Weathers Bank. North of Knobview on the Weathers land (T. 38 N., R. VI W., Sec. 1, NE. qr.) is an outcrop of flint fireclay that was opened about 1887. It was not operated until the spring of 1893, when 60 tons were shipped to St. Louis by A. A. Beezley, who leased

it on a royalty of 7½ to 10 cents a ton. A pit opened in the side hill for a distance of 25 feet, shows from 5 to 10 feet of clay. The clay is capped by 3 feet of white to gray, coarse sandstone, which dips at about 10 degrees to the north. The upper two feet of the clay is soft and plastic, and then changes into the hard non-plastic variety. It is not uniform in either color or texture, but it varies from light gray to dark gray to drab in color, with occasionally red stains from iron. It varies from very fine to very coarse in grain. The location is at the base of a gentle hill, on a stream called Clear creek. A shaft 30 feet deep was sunk for coal 25 years ago to within a few feet of the clay. A seam of lignite 3 to 4 inches thick was struck, under which was a black pyrite shale that continued to the bottom of the shaft. The shaft discloses an overlying sandstone that dips about 35 degrees to the south, or in the reverse direction to the sandstone over the clay, which with the numerous sandstone outcroppings in the vicinity shows that the pit was operated at about the center of the basin.

Crawford Bank. Two miles west of Knobview and one-fourth mile north of the St. Louis and San Francisco railroad, on the Crawford farm, is a flint fireclay bank from which a car load of fireclay was shipped in 1892 to St. Louis.

Other Deposits. Flint fireclay is said to have been struck in digging a cellar on the Keinzley farm one and one-half miles north of Knobview, on the Wood place, in the midddle of section 19 (Tp. 38 N., R. V W.), and three miles west of Knobview on the Nichols land.

ST. JAMES.

This was an active shipping point for flint fireclay from 1882 to 1889, when competition became too keen. Shipping began from a number of banks, when the clay brought $2.75 a ton in St. Louis, of which $1.00 was for freight; later the freight rate was 75 cents, but competition from the banks along the Wabash railroad forced the prices to .90 and $1.00 on board the cars at the shipping point, since which time little has been done. The following is an approximate estimate of the shipments:

1882	65 cars, or	1,300 tons.
1883	160 cars, or	3,200 tons.
1884	160 cars, or	3,200 tons.
1885	160 cars, or	3,200 tons.
1886	100 cars, or	2,000 tons.
1887	100 cars, or	2,000 tons.
1888	100 cars, or	2,000 tons.
1889	100 cars, or	2,000 tons.
Total	945 cars, or	18,900 tons.

In the last year the price dropped to 65 cents a ton on board the cars at St. James. Shipments are still made, but the amount is small. An 8-ton cupola was erected for calcining the clay, as the calcined clay brought $2.50 a ton, but it did not prove a financial success.

Dawson Bank. West of St. James about three-fourths of a mile and 500 feet north of the St. Louis and San Francisco railroad (Tp. 38 N., R. V W., Sec. 30, SW. qr.) is the Dawson bank. It was opened in 1886, and over 2,500 tons were extracted. It is 50 feet in diameter. It is about worked out, as the sandstone is exposed on all sides, which as usual, dips towards the center of the pit. About 500 feet west of the Dawson pit, at the same horizon, is a quarry in the magnesian limestone.

Buskett Bank is one mile north of the town (Tp. 38 N., R. VII W., Sec. 18, NW. qr.) on the edge of the breaks of the prairie, and at the crest of a gently sloping hill. It was opened in 1883, and operated until 1888 on a royalty of 10 cents a ton. Since then it has been operated by Louis James, who took out 2,000 tons. The clay is white

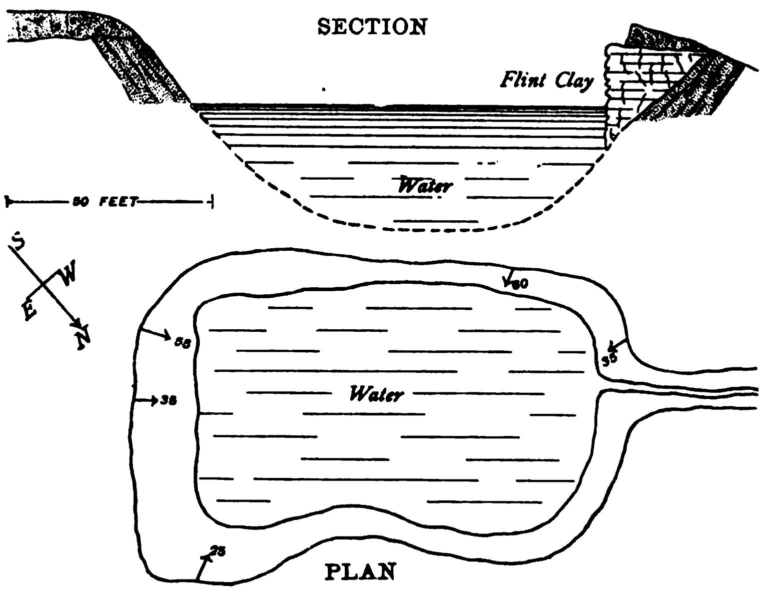


Figure 13. Buskett Flint Clay Pit.

to faint buff in color, very compact, hard, and non-plastic. Towards the sides it is somewhat stained by iron, and becomes coarse and sandy, but there is a sharp line, between the sandy clay and the bottom sandstone. This clay is overlain by 4 feet of soil and chert gravel. The pit is about 125 feet long, 80 feet wide, and 15 to 30 feet deep. It is flanked by a white to gray, coarse-grained sandstone on all sides, which dips at angles of 25 to 60 degrees toward the center of the basin.

The clay was mined for 20 cents a ton, hauled to the station for 30 cents, weighed for 5 cents, and paid a royalty of 10 cents, making the total cost 65 cents a ton on board the cars. The accompanying plan and section (figure 13) is representative of the general structure of all these flint clay deposits, as the complete exhaustion of this pit, at least to water level, clearly exposes the character of the basin.

Bowman Pit. One hundred yards east of Buskett is the Bowman pit. The clay is covered by three feet of soil and gravel that have to be stripped in working. The pit is almost circular in section, and is about 150 feet in diameter, with banks 10 to 18 feet above the water level. The west and south sides of the bank end in heavily stained brown to red fireclay. Sandstone flanks the north face dipping into the pit at an angle of 50 to 60 degrees, and also on the east bank, where it dips 40 degrees. It was opened in 1883 by Mr. Breen, who shipped 20 tons. About 15,000 tons have been shipped from this bank.

Matlock Bank. Northwest of the town about two and one-half miles, on the Jefferson City road (Tp. 38 N., R. VII W., Sec. 11, NE. qr.) is the Matlock flint fireclay bank. It was opened in 1888, and about 800 tons shipped. It occurs in a mound with little or no stripping, and is 40 feet wide and at least 30 feet deep. Another deposit occurs on this section which was discovered by plowing, but it is not developed.

Gronehalt Pit. Three and one-fourth miles north of St. James (Tp. 38 N., R. VI W., Sec. 7) is the Gronehalt bank of flint clay. It is 140 feet in diameter, and has produced about 500 tons of clay. As the hauling cost 60 cents a ton it had to shut down from the competition of the other banks.

Gray Bank is about three and one-half miles northeast of St. James. It was leased on a royalty of 10 cents a ton. The distance renders the expense of hauling so great that but little is shipped.

ROLLA.

Kelly Pit is about one mile southwest of Rolla (Tp. 37 N., R. VIII W., Sec. 11, SW. qr.). It was discovered in 1872, in prospecting for iron, but was not opened until 1883. It has produced about 700 tons. The clay rests near the crest of a gently sloping hill, and the pit shows a depth of about 8 feet, with a length of 120 feet and a width of 25 feet. It is flanked with mixed red and white clay which is said to run into clean red and blue iron ore at one place. The white clay is very hard, compact, and non-plastic and is not affected by the weather, even after an exposure of over seven years. It is well bedded, and

dips at angles varying from 0 to 30 degrees. Sandstone outcrops at the north and east ends of the pit.

Hawkins Bank. About one and one-half miles east of the town (Tp. 37 N., R. VII W., Sec. 6) a bank was discovered in 1891, but only one car or 20 tons was shipped up to the fall of 1893.

Other Pits. Seven miles north of Rolla in grading through a ridge on the Vichy road, a pocket of white to red fireclay was struck in the southern half of section 2 (Tp. 38 N., R. VIII W.)

MARIES COUNTY.

Not possessing a railroad it is impossible for the county to profitably ship flint fireclay, as it cannot stand the expense of hauling. There has not been an incentive therefore to prospect for it, and the few occurrences that are known in the eastern part, especially in the Lane Prairie district, have been found by accident. The Lane Prairie district is likely to be rich in flint fireclay deposits when there is an inducement to search for them, but on account of its gently rolling character, it will require test-pitting or boring to find them. The eastern half of the county is almost certain to prove rich in these clays, and the portion west of the Gasconade river may also prove productive when the shipping facilities permit the working of the deposits.

Vienna. About four miles northeast on the Crum land there is a deposit of flint fireclay outcropping on a branch, also in a ravine one-half mile northeast of the Crum place.

Lindell. About one and one-half miles northeast (T. 40 N., R. VIII W., Sec. 25, NE. qr.) on the Jones land, white flint fireclay was struck in digging a cistern. It is a fine-grained clay of excellent quality, though intermixed with some red-stained clay. It is on the northwest edge of Lane prairie, which is very gently rolling, so that no outcrops would be visible.

Three miles east of the town on Lane Prairie (T. 40 N., R. VIII W., Sec. 29, NW. qr.) a plastic, white clay crops out for about 75 feet in a small wash near the Union road, and seems to be the weathered outcrop of a pocket of flint fireclay.

Grovedale. About three miles southwest, red flint clay crops out in a ravine by the Union road (T. 40 N., R. VII W., Sec. 21, SE. qr.) It rests on a sandstone, which is at least 40 feet thick, that is underlain by brown limestone.

One and one-half miles east of the town on the Bowles land, flint fireclay is said to occur about one-half mile north of the St. Louis road. It is also reported three miles north of Grovedale on the Palmer place.

GASCONADE COUNTY.

Gasconade county is very rich in flint fireclay, especially in the neighborhood of Owensville and Brake. The quality is excellent and the deposits are numerous, but as there is no railroad within 15 to 20 miles of the clay banks the product is prevented from reaching the market. The central portion of the county seems to be the richest.

CLEAVESVILLE.

There are numerous outcrops of flint fireclay in the neighborhood of Cleavesville (T. 41 N., R. VI W.), but they have not been carefully investigated as yet.

OWENSVILLE.

Flint fireclay occurs more abundantly in the neighborhood of Owensville than at any other place in the state. It is almost valueless at present on account of the lack of shipping facilities, but the projected extension of the St. Louis, Kansas City and Colorado railroad from Union, in the adjoining county, would make them available. The numerous banks that have been opened are due partly to prospecting and partly to accidental discovery. The clay has been used for road metal or macadam to a limited extent about Owensville, on account of its being one of the most available materials, rather than from its durability. as it is too brittle and too soft to withstand the wear of traffic. It is stated to occur on every farm about Owensville, which is quite probable, but it appears to be more abundant north and east of town, along the breaks of Douglas prairie. This is probably due, however, to erosion rendering it visible, whereas it is usually covered by 2 to 10 feet of soil on the level prairies. Several small pockets of coal also occur in the neighborhood of Owensville, but thus far none of workable thickness have been discovered. There is usually a heavy body of black shale associated with the thin coal seams and occasionally a fireclay that is hard and non-plastic. The clay of which the analysis was made is one of this type.

The places in which flint fireclay are known to occur near Owensville are as follows: Buchanan farm, one-half mile northwest of Owensville (Tp. 42 N., R. V W., SW. qr.); Know farm, one and one-half miles west; Pattmeyer place, on the Springfield road in Owensville; Kuehne place, at the blacksmith shop in town; Kuehne land, one-fourth mile east; Pattmeyer land, three-fourths of a mile northeast; Pappenhouse land, seven-eights of a mile northeast; Sessman land, one mile northeast; Vaughn farm, one and one-half miles northeast; Matthew land, three miles northeast; and Howard land, four miles northeast.

A sample of the flint fireclay from Owensville gave the following results: Color black, which is due to organic matter, as it burned white, on the soft weathered faces gray. Texture massive, compact, hard (2.0 to 2.5), uniform and fine-grained. Taste, lean and gritty. Slacked readily into coarse granules one-tenth to one-half inch in size. Pyrite was not noticeable, but sand (quartz) was rather abundant as rounded grains. When crushed to 20-mesh and mixed with 15.0 per cent of water it formed a lean paste that shrunk 3.8 per cent on drying and 4.3 per cent when vitrified, giving a total shrinkage of 8.1 per cent. The dried mud had an average tensile strength of 32, and a maximum of 38 pounds to the square inch. Incipient vitrification occurred at 2,050° F., complete at 2,200°, viscous above 2,350°. It burned to a white, compact, rather strong body when vitrified. It dried rapidly and heated without cracking.

A chemical analysis gave:

	Per cent.
Silica	44.70
Alumina	35.92
Combined water	12.20
Moisture	0.42
Iron sesquioxide	3.35
Lime	3.00
Magnesia	0.21
Alkalies	0.29
Total	100.09

DRAKE.

The flint fireclays are believed to be nearly as abundant at Drake as at Owensville. There is one very large bank or mound about three miles north of the place which is said to afford a very superior quality of clay. A sample gave the following results: Color light gray, with slight yellow to brown iron stainings. Texture massive, uniform, compact, hard (2.5 to 2.8), very fine-grained. Fracture conchoidal. Taste, very lean. Slacked very slowly and very imperfectly to one-eighth to one-half inch granules. Pyrite was not noticeable. When ground to 20-mesh and mixed with 17.0 per cent of water it made a lean paste that shrunk 3.3 per cent in drying and 10.5 per cent when vitrified, giving a total shrinkage of 13.8 per cent. The air-dried mud had an average tensile strength of 14, and a maximum of 21 pounds to the square inch. Incipient vitrification occurred at 2,300° F., complete at 2,500°, viscous over 2,700°. It burned to a white, compact, rather strong body. It dried rapidly but needed slow heating to avoid checking. Specific gravity, 2.35.

A chemical analysis gave:

	Per cent.
Silica	40.50
Alumina	43 22
Water	14.15
Iron sesquioxide	0.31
Lime	1.11
Magnesia	trace
Alkalies	0.61
Total	99.80

Between Drake and Hermann, on the Hobein farm there is a pocket of flint fireclay that is surrounded by sandstone.

OSAGE COUNTY.

Osage county has an abundance of flint fireclay deposits especially the central and southern portions, but the clay banks are too far from the railroad to be profitably worked, as the haul is from 10 to 15 miles to the Missouri Pacific railroad, or to the Missouri river. As the entire county is underlain by the Ordovician limestones it is not unlikely that pockets of flint clay will be found in the northern portion that will admit of profitable shipment. Thus far no shipments have been made from this county, nor can there be under existing conditions.

LINN.

Garstang Pit. About one mile northeast of Linn (Tp. 43 N., R. VIII W., Sec. 5, SW. qr.) there is a deposit of flint fireclay on the Garstang land. A prospect shaft was sunk to a depth of 13 feet which disclosed a solid body of light gray clay of excellent quality. It is covered by three feet of soil and chert, but enough work is done to show that the deposit is over 75 feet in diameter, and therefore of considerable magnitude. No shipments have been made from this bank, as it is too far from the railroad. The following tests and analysis show that it is an excellent flint fireclay: Color very light gray, with slight yellow to red iron stains and black organic stains on joints; also a few black specks inside. Texture massive, compact, uniform, hard (2.5 to 3.0), and fine-grained. Taste, very lean. Slacked not at all. Pyrite was not noticeable. When crushed to 20-mesh and mixed with 16.5 per cent of water it made a very lean paste that shrunk 3.5 per cent on drying and 10.3 per cent when vitrified, giving a total shrinkage of 13.8 per cent. The air dried mud had an average tensile strength of 24 and a maximum of 25 pounds to the square inch, when ground to 20-mesh, and 60 pounds when ground to 100-mesh. Incipient vitrification occurred at 2,250° F., complete at 2,450°, viscous above 2,600°. It burned to a gray, rather strong, compact body, when vitri-

fied, dried rapidly but required to be burned and cooled slowly to avoid checking. Specific gravity 2.38.

A chemical analysis gave the following results:

	Per cent.
Silica	47.84
Alumina	37.14
Combined water	13.18
Moisture	0.37
Iron sesquioxide	0.83
Lime	0.42
Magnesia	0.58
Alkalies	0.50
Total	100.86

Two hundred yards south of the above mentioned, a shaft 11 feet deep showed an almost solid mass of brown to dark-red flint clay, under about two feet of stripping. It was discovered under the roots of an overturned tree. About three-eighths of a mile northeast of the Garstang bank on the Franken land, flint fireclay crops out on a small branch. It is surrounded by sandstone and some of the outcropping clay is soft and plastic. No work has been done to disclose its magnitude or quality.

Two and one-half miles southwest of Linn, near the crest of a hill on the Westphalia road, on the Vogel farm (Tp. 40 N., R. IX W., Sec. 23, NE. qr.) outcroppings of red and white flint clay occur on the roadside that indicate a pocket over 100 feet in diameter. Most of it is a light colored, fine-grained clay of excellent quality. About 100 feet to the west on the Laughlin land another pocket crops out by the roadside, which seems to be over 60 feet in diameter and of excellent quality. A mixed gray and white flint clay also crops out 200 yards southeast of the preceding exposure. Another deposit is exposed in a field about 100 yards to the north. All these outcroppings, which are on or near the Westphalia road, occur near the edge of a high prairie, where erosion has had an opportunity to expose them.

About two and one-half miles west of Linn flint fireclay occurs on the Turner place.

RICH FOUNTAIN.

Two miles north of Rich Fountain a light gray flint fireclay occurs on the Ohelven farm, which appears to be a fairly good grade.

FREEDOM.

West of Freedom about two miles flint fireclay is said to occur on the Rhodes place in the northern part of section 7 (Tp. 43 N., R. VII W.)

BELLE.

About one mile northeast of Belle flint fireclay crops out on the edge of Galloway prairie.

MORGAN COUNTY.

No flint clay is shipped out of Morgan county but deposits exist of more or less purity, and outcroppings are very favorable for the development of extensive pockets. Although there is a gap of 50 miles between Versailles and the nearest known workable deposits of flint clay in Linn and Osage counties, the geology is favorable for the discovery of more or less abundant deposits of this type of fireclay, throughout the county. The county is not favorably situated for reaching the St. Louis, Chicago, or the eastern markets, on account of the long haul, but it is favorably situated for the western markets, although these are not yet very large.

Northeast of Versailles about one-half mile, near the creamery, in a small ravine, is an outcrop of sandy, white flint fireclay. About 3 feet are exposed under a capping of soil and chert gravel. Two and one-half miles east and one-half mile south of the Jefferson City road a bank of mixed flint fireclay is exposed at the base of a hill. Chert bowlders are so intermixed through the clay as to render it valueless, and its sole importance lies in its indication of the probable proximity of other banks. About 1000 feet northeast of the above bank of mixed chert and flint clay are outcroppings of light gray, mixed with some purple, flint clay, on the flank of a hill facing a small branch. The outcroppings are exposed for 100 feet along the face of the hill, and seem to indicate a large deposit. It is surrounded by sandstone which forms the bed of a neighboring creek.

ST. CLAIR COUNTY.

St. Clair county is about 100 miles west of the nearest developed flint clay deposits and thus far only indications have been found of the occurrence of flint fireclay pockets. These are in the neighborhood of Baker. This county is mainly underlain by lower Carboniferous and Ordovician limestones in the eastern and central portions, where the flint clays are most likely to occur if they exist. The Baker prospects are in the lower Carboniferous, and they are very encouraging in suggesting the probable occurrence of large pure bodies of flint fireclay.

About two miles east of Baker, on the Osage river (Tp. 29 N., R. XXIV, W., Sec. 5, NE. qr.) on the Moore land, is an outcrop that suggests the possibility of workable deposits of flint clay in the immediate neighborhood. On a gentle hillside, within 100 yards of the river, a pit has been sunk to a depth of nine feet. On the dump was chert, "tripoli," sandstone in irregular fragments, and a little flint fireclay.

The white sub-crystalline Burlington limestone outcrops all around, indicating that it is only a local or basin deposit. About 300 feet southeast of this prospect hole and within 50 feet of the Osage river, a deeply yellow-stained sandstone crops out in a ravine that contains fragments of chert and some light gray flint fireclay. In neither of the above occurrences is the flint clay in large enough amounts to be valuable but it is a strong indication of the possible if not probable occurrence of bodies of pure clay in the immediate vicinity.

CHAPTER X.

PLASTIC FIRECLAYS.

DISTINGUISHING CHARACTERISTICS.

The term fireclay is used so indefinitely that it is necessary to define what is meant by this word. Miners use the term fireclay in a very broad sense for any clay that is found underlying coal seams, without reference to its refractory character; hence it may mean a clay that is highly resistant to heat or it may not. Yet as the under-clays of coal beds resemble one another very strongly and as the refractoriness can only be determined from actual test or from an analysis, it is a very convenient field term for designating the dense, hard, plastic clays that almost invariably occur beneath coal seams, and which are frequently true fireclays. The manufacturer and user of refractory materials apply the term to the clays that are capable of withstanding a high heat, irrespective of their mode of occurrence or appearance. While this latter interpretation would seem to be clear and decisive it has the very serious disadvantage of depending upon an arbitrary estimate as to what is meant by a high heat. For some purposes a fire-brick does not have to stand a higher temperature than 2,100° F.; yet some clays that are capable of withstanding this heat would melt or fail at 2,500°, while for some other purposes a clay must be capable of withstanding a temperature of 2,700°, or a dazzling white heat. Such an intense heat as the latter is very exceptional, however, and is more than the majority of fire-brick will stand. The term fireclay is therefore largely relative and an arbitrary line has to be drawn in discriminating between those clays that are refractory and those which readily yield at moderate temperatures. The most impure and most fusible clays are capable of withstanding a bright red heat, while the purest clays are not capable of withstanding the heat of the electric arc or the oxy-hydrogen furnace, the former of which is becoming more extensively used every day. It depends on the specific application of a clay as to the temperature to which it may be exposed and as this varies more or less with every use of refractory materials in the arts, any arbitrary line between the refractory and the non-refractory clays is to

a certain extent individual. It is therefore better to use the term refractory clay for those clays that are capable of resisting a high heat on account of its very extensive and convenient employment for a class of clays the mode of occurrence of which and the physical characteristics deserve a specific name, and for which the miners and geologists have appropriated the term fireclay. The term refractory clay is preferable to fireclay as being more clear and free from any possible misconstruction, in designating the clays that are capable of resisting a high heat, and its use is warmly advocated; but as the firebrick trade tenaceously clings to the term fireclay as indicating a very refractory clay it is premature to insist upon its adoption in spite of the word having been already appropriated by miners and geologists to designate a particular mode of occurrence and appearance, whether refractory or not.

In drawing the arbitrary line as to when a clay may be termed refractory the temperature of 2,500° F. is adopted. Any clay that can successfully stand this temperature is sufficiently refractory for the great majority of uses of fire-brick, this being the temperature of a pure white heat. It is with the greatest trepidation that the term white heat is used from the fact that it will be so largely misunderstood. Aside from the difficulty of an untrained eye incapapable of discriminating between shades of color at high heats, many workers of furnaces and kilns have been incorrectly taught as to the temperatures and heats of every day occurrence, and the fault is invariably to over-estimate the temperature. The blunder is very frequently made of calling moderate orange or cherry heats, a white heat, though they range from 600° to 2,100° F.; while it is very common to hear statements made by experienced kiln-burners and managers that their wares are burned at 3,000° and upwards, which, if true, would melt the goods completely. The old, faulty pyrometers are largely responsible for this as well as the discomfort and trouble occasioned in trying to determine high temperatures by the eye. The unit adopted is 2,500° F., as this is as great a heat as can be attained in most furnaces, and it exceeds the maximum temperature to which most firebricks are exposed. It is therefore a safe point in the applications of firebrick and it is easily recognized by the trained eye. It is also a temperature that clays which are recognized by the trade as being true fire or refractory clays can successfully resist. Such clays that are capable of withstanding higher heats than 2,500° F. are called "very refractory," which indicates that they are decidedly above the average.

Of 52 Missouri clays that would be designated as fireclays by miners (from their appearance and mode of occurrence) 28 were

found to be capable of withstanding 2,500° F., while 24 yielded before reaching this temperature (or a true white heat). Among the 28 refractory clays were many well known, recognized, high-grade, true fireclays; yet in appearance they differed but little from the other 24 that proved incapable of withstanding such a high temperature. In thus placing the ban on 45 per cent of the above clays as not being truly refractory, it must not be understood that they are valueless, as several withstood temperature of 2,200° to 2,400°, which would be ample for many applications in the arts. Unless care and discrimination is exercised in their use, disastrous results might follow from carelessness on the part of the fireman or attendant should he get the fires too hot, so that it has been thought wise to draw a line at a temperature that can only be attained by exceptional conditions.

Clays that are frequently incapable of withstanding the heat required in high-grade refractory goods are often valuable as potters' clays, especially if the iron or other coloring matter is such that it can readily be eliminated by washing. In fact, this is the only important, vital difference between a fireclay and a stoneware potters' clay, as in the one case the color resulting from the iron is of no importance, while it ruins the appearance of the other. Frequently the one clay is used for both purposes, and in Monroe county one of the most refractory clays known is used for pottery purposes (Williamson clay).

PHYSICAL PROPERTIES.

All the fireclays thus far found in Missouri, except the flint clays previously mentioned, occur in the coal measures under seams of coal. They form conformable beds of greater or less thickness, that usually extend over very large areas. They are massive, or free from a laminated structure, compact, dense, hard, and usually very plastic. They are commonly gray in color, though sometimes stained dark by organic matter, and are usually somewhat streaked by oxide of iron. They have the strength and appearance of a hard rock-like mass, as they occur in the freshly exposed face, and it requires drilling and blasting to economically dislodge them; but when exposed to the weather they crack and fall to pieces and are more or less rapidly converted into a pulverant mass, especially if aided by water. They readily and completely slack when the dry clay is immersed in water, and they vary from fine to coarse in the size of the grain. The plasticity is not usually eminent when freshly mined unless they are very finely ground; but on weathering they become very much more plastic. They shrink from 3 0 to 9.0 per cent in air-drying and an additional 2.0 to 9.0 per cent in burning, averaging between 5.0 and 6.0 per cent, which gives a

total shrinkage of 11.0 to 13.0 per cent. The speed with which they can be dried and burnt varies greatly but in most cases can be done rather rapidly without checking or cracking. On account of the pressure arising from the weight of the overlying masses to which they have been exposed since their formation they have a high specific gravity, from 2.2 to 2.5.

The Tertiary clays that occur in the southeastern portion of the state have not thus far proved capable of withstanding high temperatures, though they are very satisfactory for stoneware. In fusibility they range from 2,500° F. to over 2,800°, or the highest heat that can be obtained in a wind furnace. This last temperature exceeds that to which they are exposed in practice so they can meet all commercial demands excepting that of the electrical furnace.

CHEMICAL PROPERTIES.

The chemical composition and properties of clays in general, and fireclays in particular, were so thoroughly discussed in the chapter on "Chemistry of Clays" that only a brief summary of the results deduced need be repeated here.

The ideal refractory clay is the pure mineral kaolinite, or hydrous silicate of alumina, which is infusible at any temperature that can be obtained in furnace practice, and the nearer a clay approaches the purity of kaolinite, the more refractory it is, other things being equal. But while the chemical composition is extremely important in affecting the fusibility of a clay there are two highly important physical factors that also have a marked influence. They are density and the fineness of grain. The denser a clay, the more refactory it is. Hence in deciding as to the maximum amount of impurities that are permissable in a refractory clay before it becomes so fusible as to not meet the requirements of a fireclay, it is necessary to consider both density and fineness of grain. These points have been noted by earlier observers, but their importance has not been realized.

In considering the impurities that affect fusibility it is usual to regard silica, in the form of sand, and titanic acid as harmless dilutents in having no influence on the refractoriness, notwithstanding the experiments of Seger, Hoffman and others to the contrary. The evidence derived in testing the Missouri clays confirm the old idea that they are harmless and can be regarded as non-detrimental as regards fusibility, as far as such a deduction is safe when the complexity, density, fineness of grain, amount and character of impurities are considered.

Such impurities as iron, lime, magnesia and the alkalies are always more or less detrimental to refractoriness, and these are jointly called the fluxers or fluxing impurities. T -ls is to regard them all

as equally deleterious, but this is not the case. They are found not only to have different fluxing values, but the condition or form of combination of each of these impurities has a marked influence on its fluxing value. This last factor has not heretofore been appreciated, partly on account of the incomplete character of the commercial analyses that are usually given of clays, and partly from the failure to observe the marked differences that result according to the form of combination of the impurities. The following generalizations however may be made: (1) The alkalies are the most detrimental of the fluxing impurities; (2) the ferrous or proto-salts of iron are nearly as detrimental as the alkalies and are very much more detrimental than an equivalent amount of iron in the form of sesquioxide; (3) lime is less objectionable than iron; (4) magnesia is less objectionable than lime.

As it is usually easy to convert the ferrous salts of iron into the higher or sesquioxide condition, by using an excess of air during the water-smoking and the initial burning of the clay, and as these conditions nearly always exist in kiln practice, the alkalies are provisionally placed in one class, and the iron, lime and magnesia in another, in discussing their influence. For while there is probably a slight difference in the fluxing values of the alkalies (potash and soda and the much rarer lithia), and although as there is an appreciable difference between the fluxing values of sesquioxide of iron, lime and magnesia, in the absence of sufficient data that can be authoritively used in valuating their differences, it has been necessary to tentatively class all the fluxing impurities into these two groups.

The limits of the actual amounts of fluxing impurities permissible in refractory clay are 2.0 to 7.0 per cent. If the specific gravity is very low, the clay is very fine and the alkalies exceed 1.9 per cent, the clay does not usually withstand a temperature as high as 2,500° F., if the total fluxers exceed 2.0 per cent, and hence it cannot be regarded as refractory, though it may withstand a temperature of 2,200° or 2,300°. If a clay is very coarse with a high specific gravity (2.40), and with the alkalies less than 1.0 per cent it may successfully withstand a temperature of 2,500°, though it may contain as high as 7.0 per cent of fluxing impurities. Between these two limits occur all the clays that are commercially used for firebrick and other refractory ware, and reference is made to the chapter on the "Chemistry of Clays" for details as to the definite amounts that are permissible.

As color is of no importance in firebrick, the amount and condition of the iron is of no serious moment if insufficient to affect the refractoriness. Hence the black spots or mottled appearance that is usually exhibited and which results from the decomposition of the

iron pyrite does not injure it, if in finely divided condition. If the pyrite occurs as occasional large nodules or concretions, it is very serious if not picked out, as they are liable to melt and slag through the brick.

DISTRIBUTION OF REFRACTORY CLAYS.

The plastic clays that are sufficiently resistent to withstand a temperature of 2,500°F. and upwards are confined in Missouri to horizons near the base of the coal measures. All the strictly refractory clays thus far found in the state outside of the flint clays occur in beds just above the lower Carboniferous. There are very extensive beds of so-called fireclays in the "upper" coal measures, and some seemingly high grade fireclays in the Tertiary formations, but none of them when tried, were found to come up to the requirements of a first-class firebrick, though many of them are excellent stoneware or potters' clays, as they can stand from 2,000° to 2,300°. The chief seams of plastic refractory clay at present known are found in the eastern portions of the state and they are very extensively worked in St. Louis, Audrain, Callaway and Boone counties. They are likely to be found in the counties in which the base of the coal measures occur, or in Clark, the northeastern part of Lewis county, the southern portion of Scotland, the eastern portion of Adair, Macon and Randolph counties, the western portions of Shelby and Monroe counties, the southern portions of Ralls, Howard, Chariton and Carroll counties, Saline county, the western portions of Pettis and Benton counties, and possibly in the southwestern portion of Henry county, the western portions of Cedar and Dade, the southeastern portions of Vernon and Barton counties and the northwestern portion of Jasper county. It is beyond doubt that the counties in the northeastern portion of the state above mentioned contain in workable amounts seams of sufficient purity.

The total output of plastic fireclay at present amounts to about 209,000 tons, which is valued at the point of shipment at an average value of $1.00 a ton, or a total of $209,000. The output is steadily increasing under normal business conditions.

ST. LOUIS COUNTY AND CITY.

Cheltenham Seam of Fireclay. Wherever the coal measures occur in the city and county of St. Louis, a persistent, very important bed of fireclay is found resting on a ferruginous sandstone. The latter is the basal member of the coal measures, and surrounds the St. Louis or lower Carboniferous limestone. The seam of fireclay varies greatly in purity, physical properties and thickness, but it never entirely thins out. It varies from 3 feet in thickness, at a small outlying basin near

Kirkwood, to 30 feet, near the Chain of Rocks, and averages from 5 to 8 feet. On account of the persistence, importance, and the large extent to which the clay is utilized in Cheltenham it is designated as the Cheltenham Fireclay Seam. In the accompanying map of St. Louis county (plate x) the localities at which this seam is worked are shown, as well as the area of the coal measures at the base of which the fireclay occurs at a depth of 5 to 120 feet below the surface.

The Cheltenham fireclay varies from light to dark gray in color, except at or near the outcrop, where it is always heavily stained yellow, from decomposition of the iron pyrites that it contains. It is very hard, compact and massive when freshly mined, and appears to the devoid of plasticity, but when finely ground, or weathered, it becomes very plastic. When used for the lighter grades of ware, it is always weathered one-half to three years, and occasionally for six or seven years. This not only increases the plasticity, but renders the clay more uniform, tractable and safer working. The clay is usually very coarse-grained, and noticeably sandy, though occasionally it is fine-grained and seemingly free from grit. It has a very high density that is characteristic of most coal measure fireclays, and its specific gravity ranges from 2.40 to 2.47. It requires from 14.0 to 20.0 per cent of water to make a stiff, plastic mud, which shrinks from 6.0 to 9.0 per cent in air-drying, and an additional 4 0 to 8.0 per cent when burned to vitrification, giving a total shrinkage of 10.0 to 15.0 per cent. On account of the variation in the fineness of the grain, the plasticity, as measured by the tensile strength, varies from 80 to 250 pounds to the square inch, though usually about 100 pounds.

The unusual coarseness of grain and the high density renders the clay eminently refractory, and so that it can be heated to 2,500° to 2,700°F., before failing, in spite of having from 5.5 to 7.5 per cent of fluxing impurities. This is very high for a fireclay. If some of the iron and other fluxing impurities are removed by washing the refractoriness is greatly increased, and it can withstand 2,700° and upwards, which exceeds the highest temperatures of steel or glass furnaces.

The principal fluxing impurity is iron, which usually occurs in the form of pyrite, or the bi-sulphide of iron, as small disseminated crystals; it occasionally amounts to 5.0 per cent, but usually ranges from 2.0 to 3.0 per cent. The lime varies from 0.4 to 1.25 per cent and the magnesia from 0.05 to 0.90 per cent. The alkalies vary from 0.3 to 1.1 per cent, and average about 0.6, of which the greater portion is usually potash. The sulphur shows a variation from 0.1 to 1.0 per cent, and the sulphuric anhydride or acid from 0 1 to 0.8 per cent. Titanic acid is always present usually to the extent of 1.0 per cent, and varies from

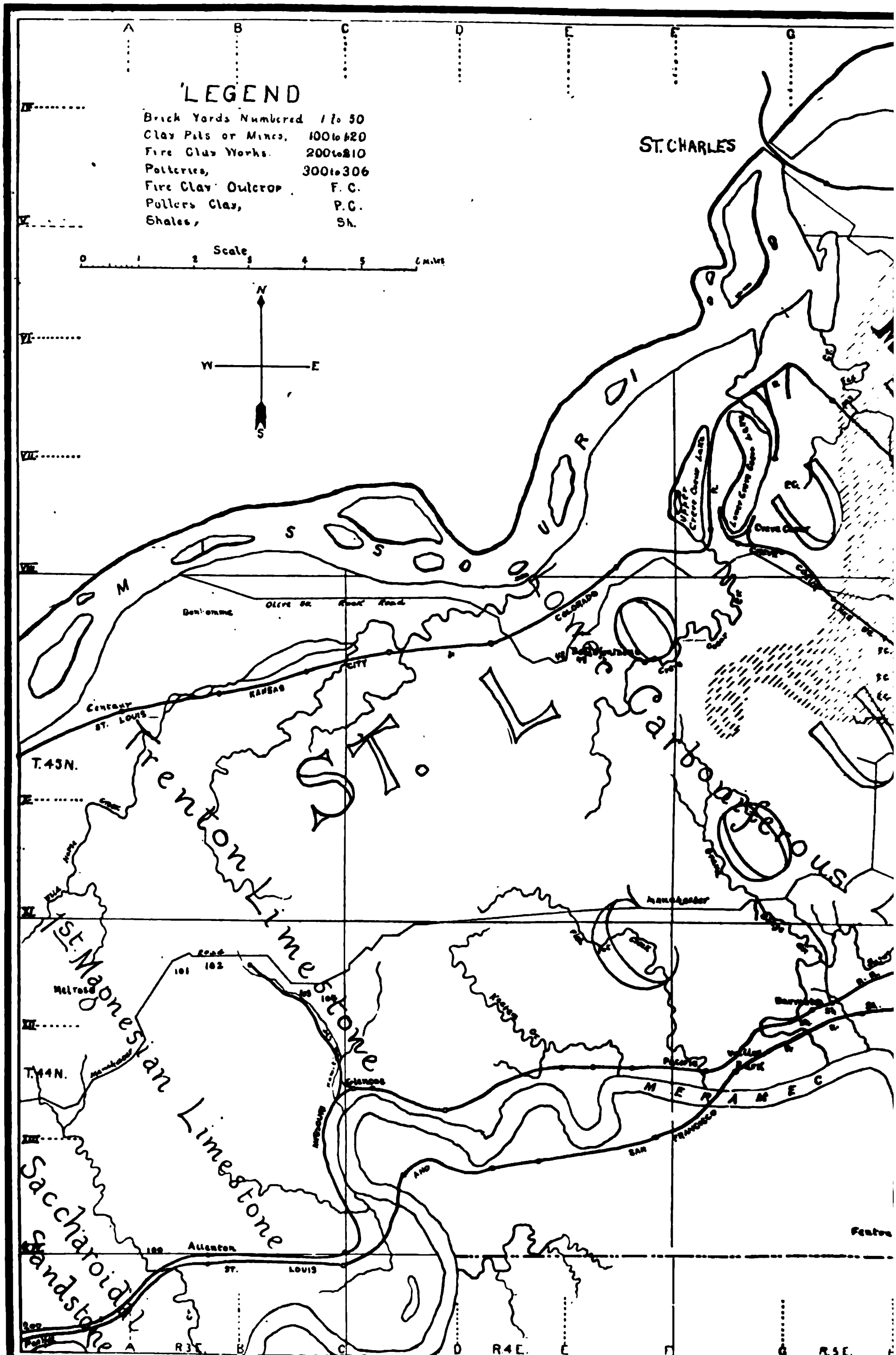
a trace to 1.8 per cent. The silica ranges from 51.0 to 68.0 per cent and averages 58.0, of which from 20.0 to 43.0 per cent is free or in the form of sand. The alumina varies from 19.0 to 31.0 per cent being lowest in the coarse clays, and highest in the fine clays. The chemically combined water ranges from 8.0 to 12.0 per cent, while the amount of moisture retained by the air-dried clay varies from 2.0 to 4.0 per cent.

The fireclay seam is usually near the surface, and often outcrops along the base of the stream valleys. The shafts seldom exceed 20 feet in depth. The seam is nearly horizontal, with only gentle dips and rolls, and it is usually overlain by a thin coal seam that is often less than one inch in thickness, though occasionally 6 to 22 inches. There is usually a zone 2 to 4 feet thick in the bed of clay that is much purer than the average, and this is selected for glass pots, zinc retorts and special purposes. This purer portion is usually in the middle of the bed, occasionally at or near the top, and sometimes in the lower portion. The upper 6 to 12 inches of the seam are generally darker on account of the presence of organic matter, and are sometimes very pyritic. The bottom of the seam is always sandy, and the fireclay usually passes into the underlying ferruginous sandstones by a transition bed of very sandy, green, very impure fireclay.

The fireclay usually has the very economical thickness of 5 to 8 feet, and on account of its freedom from water, as it is always capped by an impervious shale, it is very cheaply worked by the room and single entry system of mining. The entries are from 5 to 8 feet in width, and the rooms from 8 to 20 feet, with intervening pillars which are from 15 to 30 feet in thickness which are drawn after the rooms are exhausted. The clay is usually sheared at the sides of the room or entry with hand picks and then blasted loose with powder.

The "mine-run" or average of the Cheltenham fireclay seam sells on board the cars for \$.75 to \$1.25 a ton, and the picked or selected portions of the seam bring from \$2.00 to \$5.00 a ton, to as high as \$12.00 for pot-clay, while the washed clay sells for \$12.00 to \$14.00. The clay lands are often leased by miners who sell on the open market, on a royalty basis of 5 to 15 cents a cubic yard.

The Cheltenham fireclay seam is the source of supply of seven firebrick factories in St. Louis and of three washing establishments for supplying the glass-pot trade; it is the base of a mixture used at two large sewer-pipe plants, and it is extensively used for buff, enamelled and other ornamental brick and terra cotta at five yards. The fireclay is extensively shipped to the zinc smelters in Illinois, Missouri and



SKETCH MAP OF THE ST. LOUIS DISTRI

Kansas, and the pot-clay is shipped all over the country, as it enjoys a very high reputation for strength and refractoriness.

There are other seams of so-called fireclay in the coal measures of the St. Louis district, but they all occur at a higher horizon than the Cheltenham, and none of them are true fireclays as they are too fusible from excessive impurities. The upper seams are also thinner and less persistent than the basal one and none of them are utilized at present, though they may become of importance for stoneware and sewer-pipe.

Topographical Features of the District. As the area of occurrence of the coal measures is very irregular in St. Louis county, and as the very valuable Cheltenham seam is only found within its limits, it is im portant to distingush between areas occupied by the coal measures, and the surrounding St. Louis limestones, which latter belong to an older and lower geological horizon.

The topography usually gives an excellent idea as to the underlying formation, except when heavily covered by loess or glacial deposits. The limestones of the St. Louis area are very hard, tough, and resist mechanical disintegration, but on occount of their prevalent purity, they are very susceptible to chemical dissolution. In consequence the topography of the limestone area is charterized by basin-shaped depressions. These basins or sink-holes are more or less regularly rounded areas from 5 to 500 feet in diameter. The underground channels in the limestone, with which they are always connected, keep the basins perfectly drained, unless the entrance becomes clogged with leaves, mud, or other refuse and especially from the trampling action of animals. When thus choked they fill up more or less with water and form small, quiet ponds. These ponds frequently occupy the smaller and more recent basins, as the underground exits in the older basins tend to become enlarged by the solvent action of the percolating waters, and hence they do not readily become choked.

If the upper portion of the limestone is impure, and especially if high in magnesia, it is much more resistant to chemical dissolution, and the sink-hole method of drainage is frequently absent; but in this case the drainage is by surface channels which are abrupt and irregular, and vary sharply from gentle to heavy slopes, although the drainage lines are continuous.

In marked distinction to either the sink-hole system of drainage of the purer limestone areas, or the sharp, abrupt system where the limestones are impure, is the gentle, regular drainage the coal measures. The reason that the coal measure drainage lines are so gentle, regular and continuous is because the series of rocks (the shales

sandstones and clays) are only moderately resistant to mechanical disintegration, but they are generally highly resistant to chemical decay. They consequently readily yield to frost and erosion but are almost unaffected by the chemical action of the surface waters; hence they erode as a whole by surface or mechanical agents, instead of in local weak spots by chemical action, as in the case of the tougher, harder and stronger limestones. The drainage lines are therefore uninterrupted and regular, and usually do not have the steep slopes from the inability of the soft material, during the very long time to which it has been exposed to erosion, to retain sharp angles.

If there is a heavy covering of either loess or glacial clays that bury either the coal measures or the limestones, the sink-holes are more or less completely covered, while the gentle slopes of the coal measures are largely hidden by the new type of drainage that occurs in very soft, very recent materials. When such soft, slightly resistant material is at such an elevation as to have much slope the surface waters cut through it rapidly and deeply, and consequently change the entire topography into a series of narrow, deep valleys with steep banks. The recent deposition of the loess and glacial clays has not always enabled the erosion to cut down to the underlying limestone or shales, but it has time enough to carve and erode this young formation into a complex connecting series of sharp valleys that can be easily and quickly recognized even by the layman. As the loess or glacial clays are frequently as thick as 30 feet, this depth of covering has so completely buried the subterranean or sink-hole drainage of the limestone area, and the gentle drainage of the coal measure area, as to entirely mask the character of the underlying formations.

The three types of surface topography can be seen within a radius of a mile of the Spanish Lake in the northern part of St. Louis county. From this point to the Missouri river, which is three to five miles distant, the surface is interrupted by an almost continuous series of sink-holes of a greater or less magnitude, one of which, Spanish lake, is one of unusual size, being a basin over 1,000 feet in diameter. About a mile to the east to the banks of the Mississippi river a heavy deposit of loess gives a sharp, unbroken series of ridges, which are so characteristic of the quaternary deposits, where there is much slope. Immediately south of this point, and occupying the highest portion of the country, are the very gentle, regular, continuous drainage lines of the Watkins creek area, which is underlain by the coal measures.

A similar opportunity to compare the three different types of drainage is to be had near Florrisant, where the gentle, regular continuous drainage of the Florrisant valley is underlain by the coal

measures. Near the Missouri river where there is a heavy desposit of the loess, the drainage lines change to sharp, broken though continuous systems of ravines; while towards Black Jack and the Halls Ferry road, the drainage changes to the local, interrupted basin or sink-hole type, on account of the limestone replacing the coal measures.

The gentle, regular and uniform drainage of the head of Mill creek valley, in the neighborhood of Tower Grove which is underlain by coal measures is in marked contrast with the drainage of the Des Peres valley further west, in the neighborhood of Benton and Ellendale, where the valley is frequently interrupted by numerous local sink-holes, as the underlying formation is the St. Louis, or lower Carboniferous limestone.

Christy Fireclay Mine. This is located at the south end of the St. Louis district, at the crossing of the Morganford and Gravois roads, near Oak Hill, in the southwestern outskirts of St. Louis. The property is famous for the exceptionally high grade character of the clay that it has produced. Much of it has been used for glass-pot purposes after careful sorting as crude pot-clay and after washing, as washed pot-clay. It enjoys a very high reputation among the glass-makers, as the slagging action of the alkalies in the manufacture of glass is very severe while the strength demand to carry the load in making plate glass is very great. The glass-house service is the most severe of all demands on fireclays. The property has produced probably the largest amount of this high grade pot-clay of any mine in the country, as the greater portion still comes from Germany and England. The best quality of pot-clay which is known as crude pot-clay is obtained by careful hand-picking, in doing which any pieces that are in the least contaminated with iron or other impurities are rejected. Only a small percentage of the clay stands this rigid inspection. Most of it is deposited on a dump, where after weathering for a year or more, it is washed to free it from iron, coarse sand and other impurities. The clay that is not pure enough for lump or washed pot-clay is used in the firebrick department for common firebrick.

The company has an estate of over 350 acres that was formerly the farm of Wm. Christy, the founder, who originally mined considerable coal from a thin coal seam that occurs above the fireclay. The clay was discovered in 1857 by Mr. Christy, in digging a well near his house. He did not recognize its value until his brother James, from Philadelphia, saw the whitish clay that has been found in the well, and suggested investigating its value, with the result of finding it suitable for glass-pots. Work was carried on in a small way and crude pot-clay was shipped until 1863, when washing was begun. Pot-clay only was

shipped, which mainly went to the glass-pot factory of Coffin and Co., of Pittsburg, Pa., where it sold as high as $18.00 a ton. The plant had no direct rail connection until 1887, when J. B. Clements became the manager. He connected it by a spur from the Oak Hill branch of the Missouri Pacific railroad, and greatly enlarged the plant by adding a fire-brick department, and increasing the washing facilities.

The pot-clay appears to lie in pockets or basins, one of which is said to be horse-shoe shaped and to cover 28 acres. Up to 11 years ago the clay was obtained from another pocket about one-half mile west of the present workings, where it was said to have been as thick as 14 feet in places. The present workings are 65 feet deep and the seam of pot-clay varies from one and one-half to seven feet, averaging 3 to 4 feet. The bed is slightly rolling and is overlain by a thin seam of coal that is from 1 to 12 inches thick. Underlying the pot-clay is a greenish clay that is very fusible, from its large amount of protoxide of iron. Underneath the greenish clay is a white sandstone, below which occurs the St. Louis limestone. That the underlying limestone contains sink-holes or erosion pockets is evident from the drill holes made on the Christy estate, and also on the adjoining Russell land. This is shown by the following section, which is a record of diamond drill hole No. 8, that is kindly furnished by the general manager from a hole bored in May, 1892:

		Feet
14.	(Lacking)	0 to 40.0
13.	Fireclay	40.0 to 46.0
12.	Fireclay or shale	46.0 to 48.0
11.	Shale, greenish, soft	48.0 to 59.5
10.	Sandstone, shaly	59.5 to 61.0
9.	Sandstone, gray to yellow, soft	61.0 to 65.8
8.	Shale, green, soft	65.8 to 71.8
7.	Shale, green to red, soft	71.8 to 82.4
6.	Limestone, greenish, shaly	82.4 to 83.0
5.	Shale, green and red	83.0 to 111.0
4.	Limestone, brown, shaly	111.0 to 113.0
3.	Limestone, compact, gray (St. Louis)	113.0 to 127.0
2.	Limestone, shaly with thin seams of green shale	127.0 to 131.0
1.	Limestone	131.0 to 248.0

The clay is worked by the room and single entry system of mining in which the rooms are carried from 12 to 15 feet wide, and the pillars 30 feet. The clay is blasted with black powder, after shearing one side and is mined on contract for 28 cents a ton.

A cubic foot of freshly mined clay as obtained by cutting out a solid block is said to weigh from 161 to 165 pounds; but the specific gravity varies from 2.41 to 2.51 and averages 2.47, which gives about 145 pounds to the cubic foot. A sample obtained from the dump of the average mine run showed the following characteristics: Color

light gray, with occasional yellow to brown to purple iron stainings. Texture coarse-grained, compact, massive, rather hard (2.0 to 2.5), and not uniform. Taste, fat and somewhat gritty. Slacked very quickly and completely into a fine powder. Pyrite was not usually visible. When ground to 20-mesh and mixed with 17.0 per cent of water it made a plastic paste that shrunk 6.5 per cent in drying and 4.5 per cent when burned to complete vitrification, giving a total shrinkage of 11.0 per cent. The air-dried mud had an average strength of 114, and a maximum of 138 pounds to the square inch. It dried rapidly without cracking, but required to be slowly heated to avoid cracking. Incipient vitrification occurred at 2,100° F., complete at 2,300° and viscous at 2,500°. The clay burned to a tough, compact, brown stoneware when completely vitrified.

The washed pot-clay which was used as a standard for comparison in making all the tests on the Missouri clays, on account of its uniform excellence and national reputation, gave the following characteristics: Color uniform light gray. Texture uniform, coarse-grained, soft, and rather porous. Taste, smooth and fat, with a slight fine grit. Slacked somewhat slowly, but completely into flakes and granules one-tenth to one fortieth of an inch in size. Pyrite was not noticeable with the lens, but considerable sand was present in a fine condition. When ground to 20-mesh, and mixed with 20.0 per cent of water it made a very plastic paste that shrunk 7.7 per cent in drying and 5.1 per cent in burning, giving a total shrinkage of 12.8 per cent. Air-dried mud had an average tensile strength of 168, and a maximum of 196 pounds to the square inch. Incipient vitrification occurred at 2,200° F., complete at 2,400°, and viscous above 2,700°. An analysis of the mine-run and washed pot-clay gave the following percentages:

	Mine Run.	Washed.
Combined silica	31.39	26.03
Free silica	29.38	37.25
Alumina	23.56	21.16
Combined water	9 25	8.94
Titanic acid	0.96	1 07
Ferric oxide	4 69	1.81
Ferrous oxide	0.47	0.82
Lime	0.55	0.61
Magnesia	0.15	0 30
Potash	0.92	0.51
Soda	0.08	0.00
Sulphur	0.09	0.12
Sulphuric acid	0.35	0.56
Totals	101 84	99.18
Moisture	2.94	2.63
Total fluxers	7.30	4.73
Specific gravity	2.47	2.13

The Christy Fireclay Co. is one of the few that regularly records the purity of the washed clay by having frequent analyses made of samples that represent a week's washing. An average of three weekly analyses that were made by William Chauvenet is as follows:

	Per cent.
Silica	62 00
Alumina	24.24
Water	10 00
Sesquioxide of iron	1.90
Lime	0 30
Magnesia	0.50
Alkalies	1 06
Total	100 00

The total output of the mine is about 70 tons a day, which is raised by a steam hoist; this is picked over and sorted into three grades: (1) crude clay, which is shipped direct to to the glass works, (2) the pot-clay which goes to the factory to be washed after weathering for a year or more, and (3) firebrick clay which goes to the firebrick department to be made into various grades of firebrick.

Parker-Russell Fireclay Mine. This plant is on an extensive estate at Oak Hill, on the Morganford road, in the southwestern part of the city and about one mile north of the Christy place. The property was first worked for coal in 1820 by James Russell, and for many years it was one of the largest of the St. Louis coal mines. The coal seam is at a depth of 80 feet and has a thickness of 4 to 6 feet which is exceptional. The coal was worked by hand, and about 1,500,000 bushels a year were mined, which sold for 5 to 12 cents according to the varying conditions of the market. The last of the coal pillars was robbed about 1887, since which time the property has been exclusively operated for fireclay, of which about 20,000 tons a year are produced. In 1866 operations began on the Cheltenham fireclay seam which occurs at a depth of 117 feet.

The seam is from 3 to 7 feet in thickness. The upper portion contains the purest clay, as the lower part is more or less contaminated with greenish protoxide of iron. The clay is very coarse-grained, and contains a white efflorescence that consists mainly of sulphate of soda which shows as delicate needles on drying. The clay is worked by the room and entry system in which the rooms are carried from 18 to 20 feet wide and the pillars 20 to 25 feet thick. The clay is sheared on the side with hand picks, then blasted with black powder, and hauled in cars by mules to the shaft. There is an excellent gray rock roof over the clay and it is underlain by a green sandstone which is said to rest on the St. Louis limestone.

A preliminary examination of a sample of this clay gave the following characteristics: Color dark gray, with occasional green and yellow stainings. Texture compact, massive, hard (2 to 2.5), and coarse-grained. Taste, lean and sandy. Slacked readily and completely into coarse grains. Pyrite occurred rather freely, as crystals one-eighth to one-hundredth of of an inch in size. Sand was abundantly disseminated. When ground to 20-mesh and mixed with 15.0 per cent of water it made a plastic paste that shrunk 7.0 per cent in drying and 4.0 per cent when vitrified, giving a total shrinkage of 11.0 per cent. With 20.0 per cent of water the air-shrinkage was 10.0 per cent; with 18.0 per cent of water it was 8.2 per cent. The air-dried mud had a tensile strength of 129, and a maximum of 140 pounds to the square inch. Incipient vitrification occurred at 2,250° F., complete at 2,450°, and viscous at 2,700°.

A chemical analysis gave the following results:

	Per cent.
Combined silica	24 62
Free silica	42.85
Alumina	19.33
Combined water	7 73
Titanic acid	trace
Ferric oxide	1 29
Ferrous oxide	1.27
Lime	0.41
Magnesia	0.07
Potash	0 49
Soda	0.58
Sulphur	0.66
Sulphuric acid	0.24
Total	99 54
Moisture	2.72
Total fluxes	5.01
Specific gravity	2.44

Tole and Thorp Fireclay Mine. This location is on a spur of Oak Hill railroad about one mile west of the Parker-Russel mine and near the city insane asylum. There are 43 acres in this property and like all the adjoining land, it was formerly worked for coal. The latter was only 2 to 4 feet thick. Only fireclay is mined which is sold on the open market partly in and about St. Louis, and partly to distant points. The mine was opened in 1880 by a shaft that is 93 feet on account of being on top of a hill. The fireclay averages about 6 feet in thickness, though occasionally it is as thick as 12 feet and again as thin as three feet. It is worked by the room and entry system with rooms 10 feet wide and pillars 30 feet thick, it being the intention to draw the pillars later. The clay is sheared along the side for a distance of 3 or 4 feet and then blasted by two shots of black powder and hauled in cars by

mules to the shaft. The following is a section of the shaft as given by Mr. Jacob Thorp:

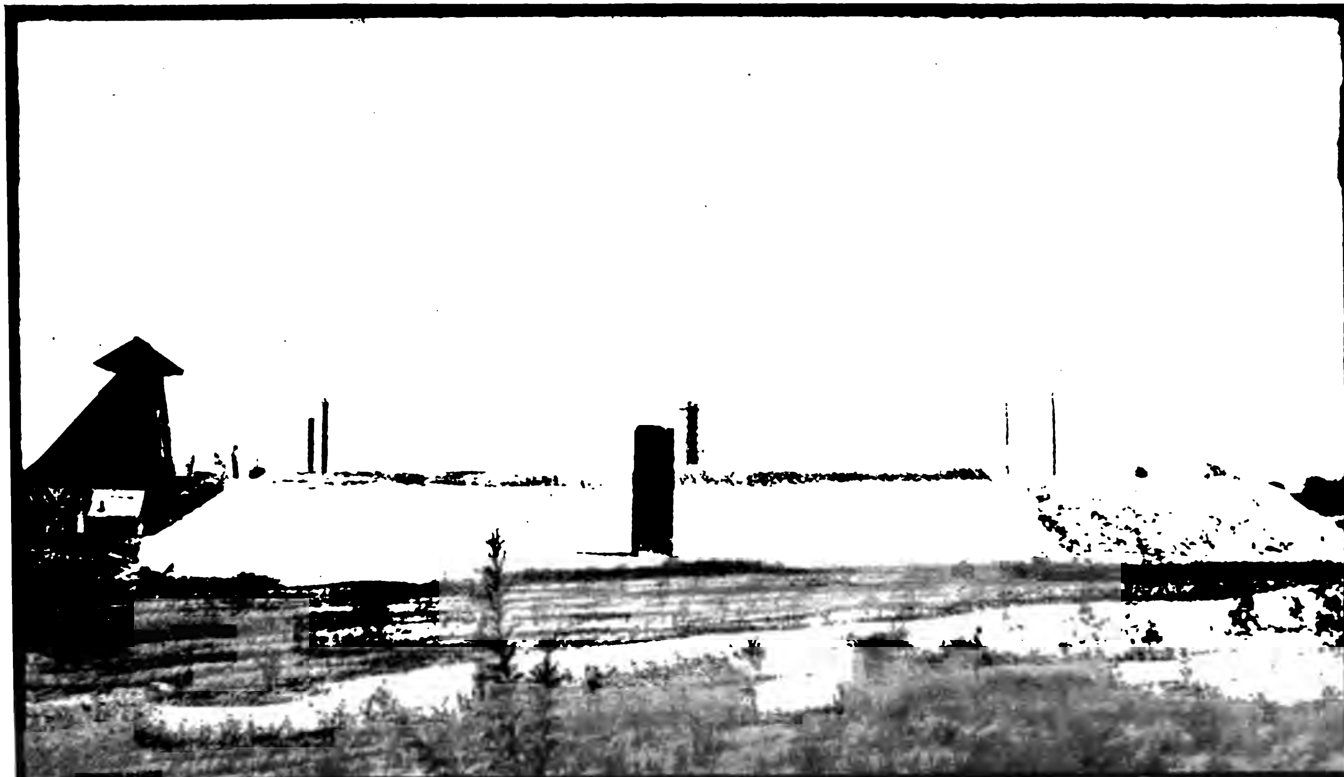
		Feet.
9.	Clay, yellow	10 0
8.	Limestone	20.0
7.	Coal, (formerly worked) average	2.0
6.	Fireclay (fusible)	10.0
5.	Flint, yellow	4.5
4.	Fireclay (poor quality, not worked)	7.0
3.	Shale, blue	13.0
2.	Sandstone, black	4.5
1.	Fireclay (worked)	13.5

The clay is largely shipped to the zinc works in Missouri, Kansas and Illinois, while the Parker-Russel, the Mississippi Glass Works and other manufacturers are extensive purchasers. The shaft is worked by a steam hoist, and the mine is producing about 50 tons a day, which is shipped direct without weathering. The quality of the Tole and Thorp fireclay is excellent, it being rather above the average of the Cheltenham seam.

Hydraulic Press Brick Fireclay Mines. Yard No. 2 is on the southwest corner of Kings highway and the St. Louis and San Francisco railroad in the western part of St. Louis. The underlying fireclay seam is operated for making buff and other ornamental brick. The shaft is 65 feet deep, and the fireclay, which is the Cheltenham seam or the one worked throughout the St. Louis district is 5 to 10 feet thick, averaging 7 feet. The fireclay is overlain by a 3 inch coal seam and is underlain by a very lean and extremely sandy clay that is green, from protoxide of iron. The clay is mined by the room and single entry system with entries 8 to 9 feet wide and pillars 20 feet, and hauled to the shaft in cars by mules. A crew of 4 diggers or miners, 5 car fillers and a driver and mule get out about 100 cars of 800 pounds or about 40 tons a day. The clay is raised through a vertical shaft by a horse gin or whim and is run out on a large dump, where it is allowed to weather for 3 to 6 months before it is used. (See plate XI.) A very superior quality of buff, Roman, enamelled, and other ornamental brick are made from the weathered clay on hydraulic presses and are burned in down-draft kilns.

Yard No. 3 of the same company is on the New Manchester road and Des Peres river, one-half mile north of shaft No. 2. The underlying fireclay is worked for furnishing clay for ornamental building brick. The shaft is 75 feet deep, and the clay averages 7 feet in thickness. The clay is utilized in the same manner as at the other yard and is similar in its general character. The output is about 40 tons a day.

Evans and Howard Mines. There are two fireclay mines that adjoin the extensive factory at Howards, in the western part of St. Louis.



WEATHERING FIRE CLAY IN ST. LOUIS.

One is on the south side of the Des Peres river, and is known as the "South" or No. 6 pit; and one is north of the same stream and the New Manchester road which was formerly known as the Wrisberg pit, but is now known as the "North" or No. 7 pit.

The South pit is the oldest or the original mine. It has furnished most of the fireclay. It is operated by a shaft on a hillside that is 65 feet deep, and the fireclay averages 7 feet in thickness. There is an overlying 2-inch seam of coal and an underlying sandstone that is over 6 feet thick, under which occurs the St. Louis limestone. The clay is worked by room and entry system, and is raised through the shaft by means of a horse whim. The clay is allowed to weather on the dump for about one yèar, and in special cases, from five tc seven years.

A sample of the clay gave the following results: Color dark to light gray, with occasional black bituminous matter and fossilized leaves and stems. Texture massive, compact, hard (2.5 to 3.0), quite uniform and coarse-grained. Taste, gritty and fat. Slacked readily and completely into coarse granules one-twentieth to three-eighths of an inch in size. Pyrite was present as occasional fine to coarse crystals. When ground to 20-mesh and mixed with 15.0 per cent of water it made a rather plastic to short paste that shrunk 6.3 per cent on drying and 5.4 per cent when vitrified, giving a total shrinkage of 11.7 per cent. Briquettes of the air-dried mud gave an average tensile strength of 78, and a maximum of 91 pounds to the square inch. Incipient vitrification occurred at 2,250° F., complete at 2,450° and viscous at 2,650°.

A chemical analysis showed:

	Per cent.
Combined silica	27.56
Free silica	30.79
Alumina	23.26
Combined water	10.20
Titanic acid	1.01
Ferrous oxide	1.72
Ferric oxide	1.34
Lime	0.65
Magnesia	0.42
Potash	0.52
Soda	0.11
Sulphur	0.39
Sulphuric acid	0.35
Total	98.32
Moisture	2.74
Total fluxing impurities	5.50
Specific gravity	2.41

The No. 7 or Wrisburg pit, on the north side of the Des Peres river, was formerly operated by the Wrisburg Mining Co., which sold

out to Evans and Howard. The clay is similar to that on the south side, excepting that it is not so rich in iron pyrites. The shaft is 45 feet deep, and the clay is raised by a horse gin. The air shaft gave the following section:

		Feet.
8.	Loess, or yellow clay	5
7.	Clay, greenish, shaly (potters)	10
6.	Gravel, chert	2
5.	Shale, red	14
4.	Sandstone, blue-gray, shaly	7
3.	Coal	1-6
2.	Fireclay (seam worked), 10 to 14 feet, average	11
1.	Sandstone, over	6

The clay from both north and south pits is hauled by wagons to the factory and used for firebrick, retorts, sewerpipe, terra cotta, and ornamental brick. For sewerpipe it is mixed with some top or yellow loess clay, to darken it, which renders the pipe more salable. Each pit produces from 75 to 100 tons a day.

Jones Mine is on the north side of the New Manchester road at Cheltenham and immediately west of the Wrisburg pit. The output ranges from 20 to 25 tons a day, for about one-half the year and is mainly sold to Evans and Howard, the Laclede Fire Brick Co., and the Missouri Fire Brick Co., at prices ranging from \$.65 to \$1.00 a ton delivered at the factory. The fireclay is 9 feet thick, and is similar to that of Evans and Howard in character and mode of occurrence. The following is a section of the shaft which is 75 feet deep:

		Feet.
5.	Loess, or yellow clay	8
4.	Potters' clay	40
3.	Shale, brown to red	13
2.	Sandrock, black	6
1.	Fireclay	9

Lagarce Pit. On the south side of the River Des Peres and Sublette avenue, in Cheltenham, a fireclay pit was opened by John Lagarce in 1890, and 100 tons were mined, on a royalty of 10 cents a ton. The pit is only worked spasmodically, and always on a small scale. The clay is sold to the Laclede Fire Brick Co. for making fire brick. The mine is opened by an entry at the base of a hill on the south side of the Des Peres valley.

Tiepelman Pit. On the south side of the Des Peres river and Sublette avenue, in Cheltenham, Wm. Tiepelman opened a pit in 1890 by driving an entry in the Cheltenham fireclay seam at the base of the south flank of the Des Peres valley. The pit has been operated only on a small scale, and has produced a maximum of 200 to 300 tons a month. The land is leased on a royalty of 10 cents a ton, and the fire-

clay sold to the Cheltenham Fire Brick Co. at 60 to 70 cents a ton delivered.

Matthieson and Hegeler Mine. This firm operates the largest zinc smelter in the country, at La Salle, Illinois, and uses about 1,500 tons of St. Louis fireclay a year for retorts. It is mined from an eleven-acre tract that is about one mile west of Cheltenham, and on the north side of the New Manchester road. From two to six men are employed and the mine is worked on the room and entry system. It is entered by a drift at the foot of a hill which saves all hoisting and pumping. The seam is about 7 feet in thickness, but only about 4½ feet of the better portion of it is taken out, the lower 3 feet being untouched, on account of the excessive amount of fine pyrites and gypsum. Gypsum crystals as large as two inches in length occasionally occur at the outcrop of the vein, but the fireclay otherwise is about the same as at the Evens and Howard and the other Cheltenham pits. The rooms are carried from 8 to 10 feet in width, leaving pillars from 18 to 20 feet, and the clay is obtained by shearing and wedging, no powder being employed. Since the pit was opened in 1863 five and one-half acres have been exhausted.

Gilker Fireclay Mine. Immediately west of the Matthieson and Hegeler pit is that of Theo. Gilker, who leases 12 acres on a royalty of 15 cents a cubic yard. The mine is opened by a drift at the base of a hill, and is worked by the room and single entry system. The entries are 6 to 7 feet wide and the rooms 7 feet wide by 100 or 140 feet long with intervening pillars 15 to 20 feet wide. The pillars are drawn or robbed as fast as the rooms are exhausted. It is estimated that only about one-fourteenth of the clay is lost or not recovered. A total crew of 11 men produce about 50 tons of fireclay a day, which is hauled to the different Cheltenham firebrick factories from one to one and one-half miles east. The St. Louis or lower Carboniferous limestone crops out about 500 feet east of the drift, and is about 10 feet lower than the floor of the clay. The clay is about 8 feet in thickness, but the lower 3 feet contain much green protoxide of iron and crystals of pyrite. The clay is also occasionally permeated with large crystals of gypsum. Excepting an unusual amount of iron the clay is similar in its properties to the usual Cheltenham seam.

Laclede Mine. The Laclede Fire Brick Co., of Cheltenham, has about 100 acres of fireclay land immediately south of the large factory, from which is mined about 50,000 tons a year. The mine is entered by a drift on the south bank of the Des Peres river, and the fireclay

averages from 6 to 7 feet in thickness. The folllowing section is exposed in the bank at the rear of the factory:

		Feet.
7.	Loess, or yellow clay	20
6.	Shale, brown to green	25
5.	Shale, black	1
4.	Sandstone, gray	6
3.	Fireclay	1
2.	Coal	1-6
1.	Fireclay (Cheltenham seam) mined	8

A view of the entrance of one of the drifts is shown in plate XII. The mine is worked by the room and single entry system, with rooms 12 feet wide by about 250 feet in length, with intervening pillars, 18 feet thick.

A sample of this fireclay gave the following results: Color dark gray, with occasional black bituminous fossil remains. Texture massive, compact, hard (2.50 to 3.00), coarse-grained and quite uniform. Taste, gritty and lean. Slacked rapidly and completely into coarse granules from one-tenth to one-twelfth of an inch in size. Pyrite was present as occasional disseminated fine crystals. On panning down or washing 2 pounds of dry clay a residue of one ounce of pyrite, or about 3.0 per cent was left. When ground to 20-mesh and mixed with 15.0 per cent of water it made a short paste that shrunk 6.0 per cent in drying and 5.2 per cent when vitrified, giving a total shrinkage of 11.2 per cent. Briquettes of the air-dried mud gave an average tensile strength of 91, and maximum of 98 pounds to the square inch. Incipient vitrification occurred at 2,200° F., complete at 2,450° and viscous at 2,650°.

A chemical analysis showed:

	Per cent.
Combined silica	32.19
Free silica	23.55
Alumina	24.68
Combined water	11.55
Titanic acid	1.60
Ferrous oxide	1.24
Ferric oxide	1.36
Lime	0.90
Magnesia	0.49
Potash	0.44
Soda	0.23
Sulphur	0.98
Sulphuric acid	0.54
Total	99.75
Moisture	2.86
Total fluxing impurities	6.18
Specific gravity	2.45

Coffin Mine. This pit is situated one mile south of Gratiot station at the junction of the Watson road and Scanlan avenue in the western

CHELTENHAM FIRE CLAY SEAM AT LACLEDE MINE—ST. LOUIS.

outskirts of St. Louis. It is on the southwestern edge of the coal measures and is flanked on the south and west by the St. Louis limestone, which is here marked by numerous sink-holes. An extensive quarry has been opened in the limestone at the base of the hill about 400 yards south of the shaft. The shaft is about 60 feet deep, and the fireclay is from 4 to 6 feet in thickness, of which from 2 to 3 feet are high-grade pot-clay. The clay is overlain by a sandstone roof, above which is a bed of red shale 16 feet in thickness. The pit was opened in 1878 by Wm. Jamison, who sold out in 1882 to Wm. Dickson, by whom it was operated for Coffin and Co., glass-pot manufactures, at the rate of about 10,000 tons of clay a year. Under this management the clay was weathered on the dump for several months, and then washed at the washhouse that is located on the River Des Peres at Gratiot station about one mile north of the clay pit. The clay is very unattractive in appearance before washing, as it is high in pyrite and limonite concretions, but these are so coarse that they readily wash out, leaving an excellent quality of pot-clay. Only about one acre and a half yields this superior quality of clay. After the failure of Coffin and Co., in 1890, the mine was shut down and was not worked again until 1895, when the American Clay Co. re-opened it and began shipping the washed clay to distant markets.

A sample of the mine-run of clay that had weathered on the dump for over two years gave the following characteristics : Color light to dark gray, with frequent yellow to brown iron stains and occasional black fossil remains of vegetable matter. Texture massive, compact, hard (2.50), and coarse-grained. Taste, rather lean and gritty. Slacked rapidly and completely into one-fiftieth to one-tenth of an inch granules. Pyrite was present as fine to coarse crystals, with occasional nodules of limonite. When ground to 20-mesh and mixed with 13 0 to 20.0 per cent of water it made a very plastic paste (weathered sample); when mixed with 19.6 per cent of water it shrank 8.8 per cent; with 15.0 per cent of water it shrunk 6.5; and with 13.0 per cent of water it shrunk 5.6 per cent. The air-dried samples shrunk 4.1 per cent when burned to vitrification, giving a total shrinkage of 10.0 to 13 per cent. Briquettes of the air-dried mud gave an average tensile strength of 235, and a maximum of 257 pounds to the square inch. Incipient vitrification occurred at 2,200° F., complete at 2,400°, and viscous at 2,600°. It required to be very slowly dried and slowly heated to avoid checking and cracking.

The analysis of the mine-run of the Coffin mine is not satisfactory, as there is but little doubt that the fluxing impurities are too low; but

as an opportunity of re-sampling and re-analyzing this clay was not found, it is given for what it is worth.

	Per cent.
Combined silica	34 35
Free silica	24.27
Alumina	26.89
Combined water	10.76
Titanic acid	trace
Ferrous oxide	1.28
Ferric oxide	0.85
Lime	1.00
Magnesia	0.32
Potash	0.21
Soda	0.26
Sulphur	0.26
Sulphuric acid	0.13
Total	100.68
Moisture	1.88
Specific gravity (average of 3)	2.44

The clay is washed at a small wash-house on the bank of the river Des Peres at Gratiot station on the St. Louis and San Francisco railroad. The weathered clay is dumped into a large "blunger" or wash vat that consists of a cylinder about 8 feet in diameter and 10 feet high, with a vertical revolving shaft that is armed with paddles. The vat is filled with water, the arms are revolved and the clay is slowly shoveled in in a more or less dry condition. The heavy impurities sink to the bottom, while the pure fine clay particles are held in suspension by the vigorous agitation. When sufficient clay has been added to bring the charge to the consistency of thin cream the revolting paddles are stopped, the coarse sand and impurities are allowed to settle to the bottom and the thin gruel of suspended clay particles is drawn off and run through a fine lawn sieve to take out any further coarse matter. The thin cream of pure clay is then run into large, shallow settling tanks, to enable the clay to slowly settle out of the water. After 24 to 48 hours settling the clay particles fall to the bottom of the tank and the clear water above is drawn off. The settled clay has the consistency of gruel, and still contains over 5.0 per cent of water, which is removed by pumping it through a filter press which takes out the excess of water and leaves behind a stiff paste in the filter bags of the press. This paste or mud is run into a small plunger mud machine which forms it into blocks that are about 10 by 5 by 3 inches. The blocks are dried on shelves set over steam pipes which dries out the last of the moisture when they are ready to be shipped to the glass works, to be worked into glass-pots. Sometimes they are calcined before shipping, to remove the chemically combined water, which also partly re-

duces the shrinkage and for this purpose there is a small round, down-draft, bee-hive kiln.

A sample of this washed clay gave the following physical results: Color uniform light gray. Texture massive, porous, soft (1.5), and uniform. Slacked rapidly and completely into one-thirty-second to one-eighth inch granules. Taste, smooth or fat and very slightly gritty. Pyrite or sand not noticeable. When ground to 20-mesh and mixed with 17.0 per cent of water it made a slightly short paste that shrunk 6.8 per cent in drying and 6.6 per cent when vitrified, giving a total shrinkage of 13.4 per cent. Briquettes of the air-dried mud gave an average tensile strength of 91, and maximum of 98 pounds to the square inch. Incipient virtification occurred at 2,200° F., complete at 2,400° and viscous at 2,600°.

A chemical analysis gave:

	Per cent.
Combined silica	35.47
Free silica	20.15
Alumina	27.85
Combined water	11.40
Titanic acid	1.81
Ferrous oxide	1 04
Ferric oxide	1 86
Lime	0.80
Magnesia	0.27
Potash	0.58
Soda	trace
Sulphur	0.12
Sulphuric acid	0.20
Total	101.55
Moisture	2.61
Total detrimental impurities	4.87
Specific gravity (average of 3)	1.99

Jamieson Pit. Immediately opposite the Coffin clay pit, on the north side of Scanlan avenue, Wm. Jamieson has two acres of land that is said to contain a good grade of pot-clay. It has not been worked since he opened a large mine near Bartolds Valley in St. Louis county.

Jamieson Mine at Bartolds. One mile north of Bartolds in St. Louis county near the Hanley road, is the fireclay mine of Wm. Jameson. It was opened in 1882, since which time it has steadily shipped washed pot-clay, though not on a large scale, to most of the glass works in the United States. There are 34 acres of land of which about 15 acres have

good fireclay that is from 4 to 14 feet in thickness. The following is a section of the shaft :

		Feet.
8.	Loess, or yellow clay	12
7.	Pipe-clay	5
6.	Shale, red	12
5.	Coal	½
4.	Fireclay	1½
3.	Shale	1½
2.	Fireclay (the seam worked)	4 to 14
1.	Sandstone	12

The property is near the southwestern edge of the coal measures, as the St. Louis limestone is exposed in Bartolds valley about a mile southwest. The mine produces a superior quality of pot-clay, of which about 10.0 per cent is crude, while the rest is washed. The workings are on the crest of a hill, and the shaft is 48 feet deep to the bottom of the clay seam. The clay is worked on the room and single entry system and the rooms are 9 to 10 feet wide, the pillars 15 to 18 feet, and the entries 6 feet. From four to six men are employed in summer, and about four in the winter, who are paid 80 cents a cubic yard for mining the clay with black powder. The clay is hoisted by a horse gin, and is weathered on the dump for two years before washing. The annual output was about 500 tons of marketable clay previous to 1889, since which time it amounts to 1,000 tons. The clay is hauled for shipment to Cheltenham, 3 miles distant, and brings $13.00 a ton on board cars for washed No. 1, or crude lump, while the No. 2 grade brings $4.00 a ton.

A sample of the mine-run showed the following characteristics: Color gray, with occasional green to yellow or brown iron stainings, and some dark to black, from organic matter. Texture massive, compact, hard (2.5), uniform and coarse-grained. Taste, lean to fat. Slacked readily. Pyrite was present in small amounts. When ground to 20-mesh and mixed with 20.0 per cent of water it made a plastic paste that shrunk 7.8 per cent on drying and 6.8 per cent when vitrified, giving a total shrinkage of 14.6 per cent. Briquettes of air-dried mud gave an average tensile strength of 113, and a maximum of 121 pounds to the square inch. Incipient vitrification occurred at 2,300° F., complete at 2,400°, and viscous at 2,600°. The clay dried readily, but needed slow heating to avoid checking.

THE JAMESON CLAY-WASHING PLANT—BARTOLDS.

A chemical analysis gave the following results:

	Per cent.
Combined silica	33.31
Free silica	19.54
Alumina	28.85
Combined water	11.61
Titanic acid	1.05
Ferrous oxide	1.42
Ferric oxide	2.77
Lime	1.01
Magnesia	0.11
Potash	0.54
Soda	0.31
Sulphur	0.34
Total	101.08
Moisture	1.75
Total fluxing impurities	6 72
Specific gravity	2.40

After weathering for two years on the dump at the shaft the clay is washed to lower the pyrite sand and other impurities, and make a homogeneous material suitable for the glass-pot trade. The clay is charged into a blunger that is 7 feet in diameter by 5 feet deep, to the extent of one ton to the charge; at the expiration of an hour the blunger is stopped and the sand is allowed to settle to the bottom. The clay slip, or fine particles suspended in water, is then run into large, shallow, wooden tanks that are exposed to the air, and the clay is allowed to slowly settle to the bottom and dry to the concistency of a soft mud. It is then removed in square chunks, hacked in open sheds and dried by exposure to the air. (See plate XIII.)

A sample of the washed clay gave the following characteristics: Color uniform, light gray. Texture massive, uniform and coarse-grained. Taste, fat. Slacked readily and completely into fine granules. Pyrite was not visible, but the weathered clay turned brown on the suface, from the decomposition of a very small amount of sulphate of iron. When ground to 20-mesh and mixed with 20.0 per cent of water it made a moderately plastic paste that shrunk 6.6 per cent on drying and 8.4 per cent when vitrified, giving a total shrinkage of 15.0 per cent. Briquettes of the air-dried mud gave an average tensile strength of 93, and a maximum of 102 pounds to the square inch. Incipient vitrification occurred 2,200° F., complete at 2,400° and viscous at 2,700°. It dried rapidly but needed slow heating to avoid checking.

A chemical analysis gave the following results:

	Per cent.
Combined silica	33.52
Free silica	20.78
Alumina	27.36
Combined water	11.13
Titanic acid	1.36
Ferrous oxide	1.13
Ferric oxide	1.60
Lime	0.87
Magnesia	0 07
Potash	0.71
Soda	trace
Sulphur	0.25
Sulphuric acid	0.51
Total	99.24
Total impurities	5.14
Specific gravity	1.92

Sattler Pits. About twenty-five years ago Geo. Sattler in mining coal from a 20-inch seam near the Chain of Rocks, in north St. Louis, was attracted by a fireclay bed that occurred beneath the coal on the Schantz land, on Watkins creek. There were 6 feet of gray, coarse, fireclay, a sample of which he shipped to the zinc works in Carondelet, and another to Illinois, but as it did not prove satisfactory, he abandoned the pits in the neighborhood of Watkins creek. Subsequently he investigated a very thick deposit of fireclay on what is now known as the Meint land, about midway between Baden and the Chain of Rocks on the Columbia bottom road. The fireclay varies from 20 to 30 feet in thickness as shown by 8 test pits put down at various times. The clay varies considerably in character and purity and in the upper portion there are usually two feet of limestone bowlders, or large rounded pieces. Occasionally at or near the bottom of the fireclay bed there is an excellent quality of pot-clay that is usually about 2 feet thick and which is very light-colored and uniformly fine-grained. It is not presistent, however, and the great portion of the fireclay is not up to the average of the Cheltenham seam as it is very pyritic with abundant disseminated crystals of pyrite, besides the large limestone bowlders previously mentioned. In order to get at the pure seam of pot-clay at the base of the deposit Mr. Sattler conceived the idea of utilizing the upper, less pure portion of the fireclay for paving brick, at which time he was the pioneer of this industry in the United States and the result of his experimenting is chronicled in the chapter on paving brick. As the paving brick venture did not prove a commercial success, the clay has not been developed to a producing point, and it awaited future development. Some of the clay by washing can be converted

nto a very fair grade of pot-clay, as the impurities are coarse enough to be largely reduced by the washing process.

A sample of the mine-run of the seam gave: Color mostly dark, with some light gray mixed with occasional greenish yellow iron stains. Texture compact, massive, hard and very fine-grained. Taste, fat, with occasional fine sandy grains. Slacked rapidly and completely into one-eightieth to one-tenth of an inch granules. Pyrite was abundant as very fine crystals.

A chemical analysis gave the following results:

	Per cent.
Silica	49.81
Alumina	30.78
Combined water	11.86
Titanic acid	1.85
Ferrous oxide	2.90
Lime	1.22
Magnesia	0.88
Potash	0.41
Total	100.29
Moisture	4 06
Total fluxing impurities	5.99
Specific gravity	2.40

A sample that was washed by hand and which is an excellent quality of glass-pot clay gave:

	Per cent.
Silica	51 07
Alumina	28.77
Combined water	11.42
Titanic acid	1.91
Ferrous oxide	2.48
Lime	0.51
Magnesia	0.87
Potash	0 58
Soda	0 43
Total	98.04
Moisture	3.68
Total fluxing impurities	4 87

Meramec Highlands. On the St. Louis and San Francisco railroad fourteen miles west of St. Louis a seam of fireclay is exposed at the base of a deep cut at the crossing of the Big Bend road. It has a thickness of 4 to 5 feet. This is a local outlier, basin, or pocket, of the coal measures, and it is at least eight miles west of the main formation at Cheltenham, As is the case with most outliers it appears to be a long, narrow trough, as it is less than half a mile in width; and where exposed in a cut on the Missouri Pacific railroad one mile north, it seems to thin out, and is very impure. The quality of the fireclay appears to be fair but it has not been utilized thus far.

ST. CHARLES COUNTY.

Outliers of the main coal basin, or the extension of the St. Louis basin, occur in the vicinity of St. Charles. A fireclay seam underlies a 20-inch coal bed, which latter was formerly worked at St. Charles on a small scale. The shaft through which the coal was hoisted has been abandoned for several years, so that no exposure of the fireclay is seen, as it occurs at a depth of about 50 feet. The fireclay seam undoubtedly occurs under several hundred acres in the vicinity of the town, but a heavy deposit of the loess hides the outcrop. No statement can be made as to the quality of the fireclay from the inability to obtain samples, but as in the Kirkwood outlier the clay may not be of the best quality.

FRANKLIN COUNTY.

No coal measures are known to occur in Franklin county and hence no regular beds of plastic fireclay are known. The county is composed of the limestones and sandstones of the Ordovican age, which occasionally contain local basins of flint fireclay referred to elsewhere. Sometimes this has weathered into a plastic condition for a few feet below the surface.

WASHINGTON.

In the neighborhood of Washington there are some interesting local deposits of fireclay in more or less circular pits, which seem at first sight to belong to the basin, or flint clay type of deposits. A study of them brings out the fact that they are plastic to the bottom, although 25 to 50 feet deep, while they are freely associated with large round bowlders, which is an phenomenon unknown in the flint clays. One of these local pits occupies a very regular, circular pit about 200 feet in diameter, that is entirely surrounded by limestone. The adjoining Kuhmiller clay pit explains its origin, as there is no doubt that it is a local accumulation of true coal measure material. The preservation of these soft, mixed materials is due to their deposition in the old depressions in the limestone, the solid, resistant walls of which have protected them from subsequent erosion. As these fireclay deposits indicate that what is now the eroded valley of the Missouri river contained basins of greater or less magnitude of the true coal measures other such deposits of fireclay are liable to be found at or near the present bluffs of the stream.

Kuhmiller Pit. One and one-quarter miles west of Washington on Noelker hill, is the fireclay pit of Louis Kuhmiller. This is a very important and extremely interesting deposit, as it has produced over 25,000 tons of excellent fireclay. The clay is fine-grained, plastic, light

gray, of excellent quality, and sell for $1.00 a ton on board the cars, after paying a royalty of 15 cents. It was formerly shipped very extenively to Blackmer and Post, of St. Louis, who used it in making a special quality of high grade sewer-pipe.

The deposit and an inspection of the plan (figure 14) would seem to indicate that it belongs to the basin type of deposits, and consists of two or three connected sink-holes that had been more or less completely filled with fireclay and the usual associated sandstone. The clay in the west face is a fine-grained, drab to dark gray clay that is very highly slickensided, and is full of large round bowlders of limestone, sandstone iron-ore, flint, and also some angular fragments of chert. The slipped faces of the clay have a general dip of about 80 degrees to the east. There are two limited exposures on the north face of green and brownish-red, soft shale that is apparently standing on edge, and which seems to be abutting against a bank of flint gravel in one case, and bowlders of joint clay in the other. The south face shows 3 to 8 feet of sandstone on edge, and is surrounded on both sides by an excellent fireclay with an intervening transition bed of 2 to 5 feet thick, of mixed clay and sandstone (figure 15). At point *A* (figure 15) is shown a break in the sandstone that has been subsequently filled by the clay being squeezed into it.

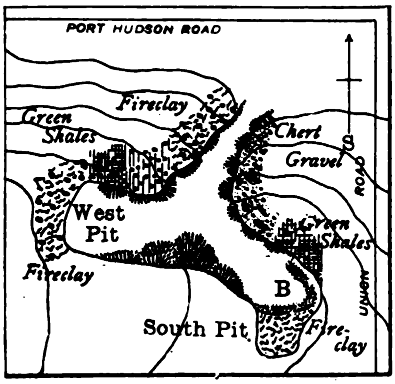


Figure 14. Plan of Kuhmiller Clay Pit.

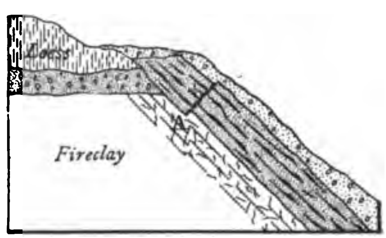


Fig. 15. Section of Kuhmiller Clay Pit.

Burchs Pit. About two miles west of Washington, and one-half miles south of the Missouri river is the Burchs clay pit. It is now exhausted, and the sides of the pit are badly washed and covered with washings from the overlying loess, so that but little can be seen. It is said to have produced an excellent quality of fireclay, which was shipped to St. Louis. A circular pit about 200 feet in diameter, and from 25 to 50 feet deep represents the volume that has been removed. A fringe of bowlders, within an interfilling of very lean, fine-grained, light gray fireclay is to be occasionly seen where the banks of the pit are now obscured by surface washings. The bowlders are from one to four feet in diameter and consist mainly of brown limestone and chert, similar to the limestone that surrounds the pit.

AUDRAIN COUNTY.

Audrain county is on the eastern limit of the Missouri coal basin, as the limestones of the lower Carboniferous occur on the north, east and south sides. On account of the gentle dip of the coal measures to the northwest, the county is favorably situated for finding fireclay near the surface as it usually occurs near the base. This basal fireclay seam is successfully worked at Vandalia and Mexico, and at the former place it seems to rest directly up on the lower Carboniferous limestone. While these are the only two places at which the fireclay is worked at present, it can probably be found by boring to a moderate depth, or from 50 to 300 feet, over most any part of the county, though it is liable to vary considerably in quality and thickness, with the chances greatly in favor of its being a good quality. Were it not for the proximity of the St. Louis district this county would undoubtedly be a very much larger producer of refractory goods, and it will undoubtedly be able to meet a very heavy demand in the future, when it has more favorable facilities for meeting railroad competition. St. Louis at present is much more favorably situated with the regard to the cheapness with which the clay can be mined, its unexcelled shipping facilities, and cheap fuel, although the general quality of the Audrain county fireclay is superior for refractory purposes.

Vandalia Mine. The mine of the Vandalia Fire Brick Co., at Vandalia, on the Chicago, Alton and St. Louis railroad, is situated at the works. The shaft is 65 feet deep, from the bottom of which are workings in both the fireclay seam and the coal that occurs above. The coal is worked by the long-wall system, and varies from 10 to 30 inches in thickness, averaging 28 inches. The fireclay bed is about 10 feet thick and consists of a uniform dark clay at the top of the seam that is 1½ to 3½ feet in thickness; at the middle is a blue clay that carries nodules of limerock, and the lower portion of the seam is light gray, and from 5 to 7 feet thick. The light clay does not have a uniform thickness as it is rather wavy, rising up into the middle blue clay, and again thinning out. The mine is worked on the room and single entry system in which the rooms are from 20 to 30 feet wide, with pillars 60 feet between the rooms, and 60 feet between the cross entries. As the rooms are usually 10 feet high, they are generally timbered with props that are set from 6 to 10 feet apart, to support the roof that overlies the coal. The miners are paid 20 cents a ton for mining the clay and 4 cents a bushel, or $1.00 a ton, for mining the overlying coal seam.

The output varies from 25 to 40 tons of clay a day, averaging nearer the former figure. The following is a section of the shaft:

		Feet.
10.	Soil and clay	31
9.	Sand	¾
8.	Shale and limestone	5
7.	Limestone, hard, blue	5
6.	Shale, black	10
5.	Coal	2⅓
4.	Fireclay, dark	3
3.	Fireclay, blue	2
2.	Fireclay, light gray	5
1.	Limestone (lower Carboniferous)	1

A sample of the fireclay had the following characteristics: Color uniform gray. Texture massive, compact, hard (2.5 to 3), and coarse-grained. Taste, lean. Slacked rapidly and completely to coarse granules one-sixth to one-eighteenth of an inch. Pyrite was not noticeable. When ground to 20-mesh and mixed with 14.0 per cent of water it made a rather short paste that shrunk 4.2 per cent in drying and 7.0 per cent when vitrified, giving a total shrinkage of 11.2 per cent. Incipient vitrification occurred at 2,300° F., complete at 2,500° and viscous 2,700°.

An analysis gave the following results:

	Per cent.
Silica	53.77
Alumina	30.90
Water	12.68
Sesquioxide of iron	1.74
Lime	0.39
Magnesia	0 32
Alkalies	0.49
Total	100 29
Total fluxing impurities	2.94
Specific gravity	2.48

A sample of 20 pounds was washed or slacked, in distilled water, and put through a 20-mesh sieve, which left a residue of ¼ pound or 1.25 per cent that consisted of coarse granules of carbonate of lime that were one-fourth to one inch in size, and pyrite concretions that were one-half an inch in size. A sample of the washed clay was made into briquettes that gave the following results: Air-shrinkage, 3.6 per cent, fire-shrinkage, when vitrified, 6.4 per cent, total shrinkage, 10.0 per cent. Briquettes of the air-dried mud gave an average tensile strength of 72, and a maximum of 83 pounds to the square inch. Incipient vitrification occurred at 2,300° F., complete at 2,500°, and viscous at 2,700°. It dried readily, but required to be slowly heated to avoid cracking.

The washed clay gave the following analysis, which shows a decided improvement over the unwashed:

	Per cent.
Silica	52.66
Alumina	30.52
Water	12.34
Sesquioxide of iron	1.42
Lime	0.28
Magnesia	0.22
Alkalies	0.52
Total	99.96
Total fluxing impurities	2.44

LADDONIA.

At Laddonia, on the Chicago, Alton and St. Louis railroad, 12 feet of fireclay are said to have been struck in a coal shaft, and also in a well that was sunk at this place.

FARBER.

At Farber, on the Chicago, Alton and St. Louis railroad, 5 to 7 feet of fireclay have been struck under a coal seam that was operated by a small shaft at this place.

MEXICO.

Mexico Mine. The mine of the Mexico Fire Brick Co. is directly under the factory near the Chicago, Alton and St. Louis railroad station. The fireclay is at the base of the coal measures, and is of the unusual thickness of 40 feet, of which only the lower 6 to 12 feet are pure enough for refractory purposes. The seam is worked by a steam hoist through a vertical shaft that is 98 feet deep to the base of the clay. The shaft has three compartments, two of which are for hoisting cages, and one for ventilation. The mine is worked by the room and single entry system, in which the entries are carried 8 feet wide, with entry pillars that are 40 feet thick, and room pillars 25 to 35 feet thick. The workings are heavily proped with ¾ sets of 10-inch timber that are placed from 1 to 2 feet apart. On account of the heavy overlying mass of clay the timbers require constant renewing although the pillars are not robbed, entailing heavy expense for timbering. The clay immediately overlying the basal 6 to 12 feet of good clay is greenish, with protoxide of iron, and hence is very fusible. A thin seam of "mother of coal" that is four to six inches in thickness is frequently found overlying the clay, which is stated to widen out into a thick coal vein, as indicated in some adjacent drillings. A force of twenty-two men is required to mine 120 tons of clay a day. The fireclay is mined by blasting from the solid for which black powder is used. The total cost of mining the clay including the timber is stated to be $1.00 a ton.

The clay is used as a "bond" or plastic clay for binding a non-plastic flint clay that is mined near Truesdale.

A sample of the clay that is used in the factory for refractory ware showed the following characteristics: Color light to dark gray, with occasional yellow to brown iron stainings and black vegetable fossils. Texture massive, compact, very hard (3.0 to 3.5), uniform and coarse-grained. Taste lean to finely gritty. Slacked readily and completely to one-thirtieth to one-eighth of an inch granules. Pyrite was present as small crystals to a slight extent, while fine-grained sand occured in noticeable amounts. When ground to 20-mesh and mixed with 15.0 per cent of water it made a lean paste that shrunk 4.5 per cent in drying and 6.5 per cent when vitrified, giving total shrinkage of 11.0 per cent. Briquettes of the air-dried mud gave an average tensile strength of 63, and a maximum of 69 pounds to the square inch. Incipient vitrification occurred at 2,200° F., complete at 2,400°, and viscous at 2,600°. It dried rapidly and heated without cracking.

The results of chemical analyses are herewith given of a sample collected and also a sample sent by the company to the St. Louis Sampling and Testing works:

	Collected Sample. Per cent.	Company Sample. Per cent.
Silica	51.40	55.12
Alumina	33 64	30.71
Water	11.48	10.56
Sesquioxide of iron	1.26	1.51
Lime	0.71	0.54
Magnesia	trace	trace
Alkalies	1.28	1.37
Total	99.77	99 81
Total fluxing impurities	3.25	3.42
Specific gravity	2.46	

CALLAWAY COUNTY.

The greater portion of Callaway county is underlain by the coal measures, except in the eastern and southern portions where the lower Carboniferous, Devonian and Ordovician rocks appear. As Callaway county is on the eastern edge of the coal basin, which dips very gently to the northwest, the coal measures are not very thick. On the contrary the drainage channels have generally cut through them, and in many places the underlying lower Carboniferous limestone is exposed. This fact is of great importance, as in consequence the basal fireclays are exposed in greater or less thickness and purity. As the county is well drained by creeks and erosion channels that are from 40 to 125 feet below the general level, fireclay outcrops are numerous. This is

especially the case in the neighborhood of Fulton, on Stimson creek and its branches. The fireclay is very thick, from 10 to 40 feet, and at least a portion of this is of high grade, and occasionally of exceptional purity. It is nearly always plastic, but a transition occurs in the neighborhood of Fulton between the plastic fireclay, and the non-plastic flint clays. There are two establishments for the manufacture of refractory ware in the county that are founded on a basal seam of fireclay, and the county could support many more, if the commercial questions of freight and fuel were more advantageous. The fireclay seam can often be worked by a drift at or near the base of the hills and a shaft does not have to be sunk far in order to reach it, under the most unfavorable circumstances.

Fulton Mine. The fireclay mine of the Fulton Fire Brick Co. is located one and one-half miles southwest of Fulton on the Jefferson City branch of the Chicago, Alton and St. Louis railroad (Tp. 49 N., R IX W., Sec. 18). The mine was opened in 1883 to work a seam of coal 2 to 2½ feet thick. It has been operated for fireclay since 1891, and produces about one car a day, which is shipped to the factory that is located in the town of Fulton. The fireclay is from 25 to 30 feet thick, of which only the lower 6 or 7 feet are mined, as the upper portion is high in pyrite and also contains some green protoxide of iron. The entire clay bed is badly slipped or highly slickensided showing considerable movement. In consequence of this, the very impure, upper, dark colored clay which is not mined, frequently comes down and cuts out 6 to 8 feet of the much purer, light colored clay; while again bowlders of chert, flint, limestone, calcite, and more or less disseminated pyrite sometimes rise up 3 to 8 feet from the floor. The mine is worked on the room and single entry system in which the rooms were formerly 8 or 9 feet wide but they have been narrowed down to 6 to 7 feet, in order to prevent the crushing of the timbers. The workings are well protected by ¾ sets, placed 2 to 3 feet apart, of 6-to 8-inch oak, that are closely lagged on the top and sides. The timbering alone costs ten cents on the ton of clay mined and by keeping it closely up to the face of the workings, the upper impure clay is prevented from contaminating the lower, purer clay. The bottom of the clay is blasted with giant powder, and a good miner gets out about 8 tons during a shift, for which 26 cents a ton is paid for mining, timbering, and traming out the shaft. The mine is worked through a vertical shaft, with a differential steam hoist. The shaft is 90 feet deep to the coal and 30 feet lower to the bottom of the fireclay. The following is a section of the shaft:

		Feet.
9.	Clay	50
8.	Limestone? buff-colored	25
7.	Limerock, brown	9
6.	Clay	2
5.	Limerock, gray	8
4.	Shale	4
3.	Coal	2 to 3
2.	Fireclay (the seam worked)	20 to 30
1.	Sandstone (exposed)	1

A sample of the fireclay collected gave: Color light gray. Texture massive, compact, hard (2.5 to 3.0), uniform, and coarse-grained. Taste, lean and gritty. Slacked rapidly and completely to one-twentieth to one-eighth of an inch granules. Pyrite was sparingly disseminated in the lower light clay and very abundantly in the dark upper clay. When ground to 20-mesh and mixed with 14.5 per cent of water it made a lean or short paste that shrunk 3.8 per cent in drying and about 7.2 per cent when vitrified, giving a total shrinkage of 11.0 per cent. Briquettes of the air-dried mud gave an average tensile strength of 40, and a maximum of 49 pounds to the square inch. Incipient vitrification occurred at 2,300° F., complete at 2,500°, and viscous at 2,700°. It dried rapidly, but needed some care in heating, to avoid cracking.

A chemical analysis gave the following results:

	Per cent.
Silica	47.30
Alumina	37.54
Water	12.76
Sesquioxide of iron	1 48
Lime	0 57
Magnesia	0 00
Alkalies	0 50
Total	100.15
Total fluxing impurities	2.55
Specific gravity	2.44

The analysis shows that this clay is exceptionally pure for a plastic fireclay and it almost approaches the purity of the flint clay in its close approximation to the formula of pure kaolinite.

Harris Mine. About one mile southwest of the railroad station at Fulton (Tp. 46 N., R. IX W., Sec. 20, NW. qr.) on the Jefferson City road is the coal and fireclay mine of John Harris. The pit was opened about 1880 for coal, and 3 acres were taken out in working a 30-inch coal seam by the long-wall system. In 1891 Mr. Harris began mining the fireclay that immediately underlies the coal, and in the following year shipped about 1,000 tons to Chicago at $1.00 a ton delivered on board cars at Fulton. The fireclay is 20 to 25 feet thick of which the upper portion is more or less greenish and contaminated with pyrite,

but the lower 7 or 8 feet are light gray and very free from impurities, except occasionally very finely disseminated crystals of pyrite. The clay is worked by rooms 7 feet wide, with pillars intervening of 18 feet and the miner or laborer is able to get out from 7 to 12 tons a day. The shaft is 65 feet deep, and it is operated by a horse whim. The following section is given:

		Feet.
10.	Soil.	1
9.	Clay, yellow	3
8.	Limerock?, hard	16
7.	Shale	3½
6.	Sandstone, white	9
5.	Shale, sandy	10
4.	Limerock, flinty	2
3.	Fireclay	5
2.	Fireclay (seam worked)	18 to 25
1.	Pyritic bowlders (exposed)	½

The quality of the fireclay from the Harris clay pit is similar to that of the Fulton Fire Brick Co., which owns 180 acres immediately south of the Harris pit. It is a very superior, pure grade of refractory clay, though it is not eminently plastic.

Minor Fireclay Deposits. As the ferruginous or basal sandstone of the coal measures is exposed in the eroded valleys around Fulton, the fireclay seam that immediately overlies it outcrops at a number of places. The usual separating stratum between the fireclay and the underlying lower Carboniferous on Stimson creek is a heavy, buff conglomerate from 30 to 50 feet in thickness. On the north side of the creek at Fulton it is capped by 1 to 40 feet of brown to yellow-colored sandstone. The conglomerate is an aggregate of coarse clean pebbles and is remarkably free from sand and clay. A typical exposure is shown in the annexed plate XIV. At the west end of this conglomerate bluff, in a small sag or basin about 8 feet deep, is a small, local pocket of fireclay.

One-fourth of a mile southeast of the railroad bridge over Stimson creek at Fulton, is an outcrop of over 15 feet of fireclay at the base of a bluff 150 feet high.

One-half mile southwest of the town, on Stimson creek, is an outcrop of the fireclay seam that was worked for a short time by Curd and Howard, until driven out by water. The work only extended to a depth of 10 or 15 feet and the clay was used at the Fire Brick Works at Fulton.

Twenty feet of fireclay are exposed on the east bank of Stimson creek about one-quarter of a mile north of Westminister college; it has a general dark color and is freely stained yellow by iron.

BASAL CONGLOMERATE OF COAL MEASURES, OVERLAID BY FIRE CLAY—FULTON.

About one-half mile southwest of Fulton, in the bed of Stimson creek (Tp. 47 N., R. IX W., Sec. 17, S. ½.) is a local pocket of fireclay resting on the sandstone. It is about 20 feet deep and 400 feet long, and follows the general trend of the creek bed. The quality of the clay is very high, and it is used by the Fulton Fire Brick Co. It could only be operated at low water, and occasionally portions of the deposit were hard and almost non-plastic.

In excavating for the insane asylum, one-half mile east of the town, a white, plastic clay was encountered that was probably an outcrop of the fireclay seam. This clay is also exposed in the bank of a small creek that flows through the grounds. Fireclay was also struck in sinking the artesian well, where it was 25 feet thick.

At the Fulton Fire Brick Co.'s factory a fireclay seam was struck in sinking a well, at a depth of 25 feet, but it was too ferruginous for refractory purposes.

About one and one-quarter miles east of Fulton, at the point at which Smith branch crosses the public road, a soft plastic fireclay is exposed in the bank of the creek.

On the Poce place, on the north edge of Fulton, on the St. Charles road, a plastic fireclay is exposed for 3 feet in the bank of a creek. This deposit is apparently only a pocket, as the brown ferruginous sandstone crops out about 100 feet further north at a higher elevation.

On the Jefferson City road, at the Morsimkoff coal mine, about one-half mile southwest of Fulton, there are 10 feet of fireclay under a 30-inch coal seam at a depth of 50 feet. Three and one-half miles south of Fulton a 30-inch coal seam is worked by stripping off 6 feet of soil. The coal is underlain by the fireclay seam, but no effort has been made to determine its thickness or quality. About 5 miles southwest of Fulton, on the south face of a hill entering the bottom of Middle river, the following section is exposed, beginning at the top of the hill:

		Feet.
12.	Soil and yellow clay	5
11.	Sandstone, coarse, ferruginous	5
10.	Limestone, gray, thin-bedded	20
9.	Shale, soft gray	2
8.	Coal, one-half inch	0
7.	Fireclay, plastic, dark colored	2½
6.	Fireclay, dark, plastic, somewhat iron-stained	2½
5.	Fireclay, coarse, gray, shaly, heavily iron-stained	4
4.	Sandstone, olive-colored, shaly	1
3.	Shale, soft, sandy	8
2.	Coal	2½
1.	Fireclay, dark gray, plastic at base of hill (exposed)	5

On the bank of the Middle river, one-fourth mile south of the above section, the ferruginous conglomerate shows from 2 to 5 feet

above the creek bed and there is sandstone 2 to 15 feet thick that is capped by 10 feet of fireclay. About one-fourth mile further east at the crossing of the Jefferson City road over Middle river, fireclay is exposed which is over 12 feet in thickness. It rests on the ferruginous sandstone. One-half mile south of Middle river at the side of the Jefferson City road gray fireclay is exposed to a thickness of five feet.

About four miles southwest of Fulton, or one and one-half miles northeast of Carrington, fireclay is exposed at the base of hill at the railroad crossing. Southwest of Fulton about three miles and two miles northeast of Carrington is an outcrop of plastic fireclay under a bed of 30 feet of shale.

CALDWELL.

North of Caldwell one and one-fourth miles fireclay is exposed at the side of the county road. It has a thickness of 10 feet and is about 30 feet below the crest of the hill, and 25 feet above the creek. It is underlain by 10 feet of sandstone. Three-fourths of a mile north of the town fireclay 10 feet thick is exposed on the county road at about 25 feet below the crest of the hill and about 20 feet above a dry run. It is underlain by conglomerate.

At the old Caldwell pottery the clay used for making stoneware is from the Fulton seam of fireclay. It was dug from an old pasture one-eighth of a mile to the north. In the immediated neighborhood, the lower Carboniferous limestone which here has a light color, outcrops in several places; it is usually gray covered by conglomerate on which rests the fireclay.

About one mile west of Caldwell, on the Bills farm, is a pocket of cannel coal associated with which is said to be 18 feet of fireclay. Eighteen cars of the clay were shipped from here to Fulton, but the cost of shipment was found to be prohibitory. On the Caldwell and Bloomfield road, a well is said to have passed through over 50 feet of fireclay. At the base of the hill in front of the house 10 feet of fireclay crops out and rest on ferruginous sandstone.

NEW BLOOMFIELD.

On the Kirby farm (Tp. 46 N., R. X W., Sec. 21) which is two miles northeast of New Bloomfield, a black fireclay occurs, but it is said to be not very refractory. On the Dennison farm near the station, 8 feet of fireclay were struck in boring for iron ore but the clay was not tested.

A sample of the New Bloomfield fireclay had the following characteristics: Color light gray, with greenish tinge on the fresh fracture, heavily stained brown by iron. Texture massive, compact, uni-

form and fine-grained. Taste, smooth and very finely gritty. Slacked rapidly and completely into one-fortieth to one-tenth of an inch granules. Pyrite was not noticeable. When ground to 20-mesh and mixed with 17.0 per cent of water it made a rather plastic paste that shrunk 5.8 per cent in drying and 9.0 per cent when vitrified, giving a total shrinkage of 14.8 per cent. Briquettes of the air-dried mud gave an average tensile strength of 58, and maximum of 68 pounds to the square inch. Incipient vitrification occurred at 2,200° F., complete at 2,400°, and viscous at 2,600°. It dried rapidly, but required to be slowly heated to avoid checking. It burned to a white, compact, strong body.

An analysis gave the following results:

	Per cent.
Silica	48.60
Alumina	35.65
Water	12.48
Sesquioxide of iron	1.95
Lime	0.51
Magnesia	0.26
Alkalies	0.49
Total	99.94
Total fluxing impurities	3.21
Specific gravity	2.27

GUTHRIE.

About one-half mile southeast of Guthrie on the Kings farm, a gray fireclay is said to have been found at a depth of 8 feet, that was over 15 feet thick. On the Reynold farm, over 5 feet of gray fireclay was struck in digging a pond. On the west bank of Smith creek about one mile north of Guthrie is the Griswell coal mine where the fireclay seam occurs under the coal. The drift enters the hill 25 feet above the creek level and ferruginous sandstone underlies the fireclay and forms the bed of the stream.

CALLAWAY.

About 1,000 feet northeast of the railroad crossing at Richland creek (Tp. 48 N., R. IX W., Sec. 28, NW. qr.) an outcrop of clay is exposed in a small branch. One-half mile west of Callaway on Richland creek coal outcrops on the bank of the stream. The seam locally thickens from 6 to 24 inches within a space of 15 feet and has several small faults of 6 to 12 inches throw. Over 3 feet of fireclay are exposed to the coal in the creek and probably it is considerably thicker. Fireclay outcrops about four miles northeast of Callaway (Tp. 48 N., R. IX W., Sec. 18), and along a branch about three miles east, under a coal seam (Tp. 48 N., R. IX W., Sec. 26, NE. qr.)

About one-fourth mile south of Steven's store (Tp. 49 N., R. XI W., Sec. 28) there is an outcrop of 5 feet of fireclay on the bank of a small creek on the Columbia road. It rests on conglomerate and is capped by 3 to 8 feet of alluvium.

At the mouth of Salt creek, one mile west of Callaway, fireclay outcrops along the bank under a coal seam.

MCCREDIE.

One mile south of McCredie (Tp. 48 N., R. IX W., Sec. 9, SW. qr.) there is said to be a black plastic fireclay. About two miles east on the Henderson farm is said to be a workable deposit of fireclay under a thin coal seam that is worked for the local consumption.

MILLERSBURG.

One quarter of a mile east of Cedar creek on the Fulton and Columbia road over 10 feet of gray fireclay are exposed at the roadside where it rests on a conglomerate that is 40 feet above the creek bed. About one-quarter mile southeast of Millersburg, where the Fulton road crosses a small creek, is an outcrop of fireclay but its thickness is not ascertained. One thousand feet south of this point, over 15 feet of fireclay are exposed under 10 feet of yellow, sandy shale. At the point at which the Fulton road crosses Miller creek there are over 15 feet of fireclay 35 feet above the creek level, resting on the lower Carboniferous limestone.

BOONE COUNTY.

Boone county is underlain by the coal measures, except in the southern portion, and in the central portions, especially in the neighborhood of Columbia. The clay is usually of workable thickness and is generally of very fine quality. In the northern portion of the county shafts of moderate depth will reach it, as the seams are somewhat too deep to be exposed by the valleys.

COLUMBIA.

Fay Pit. East of Columbia, two miles, on the east bank of Hominy creek, is an outcrop of fireclay on the Fay land, at an elevation of 100 to 125 feet above the level of the water. It is over 10 feet in thickness and rests on the lower Carboniferous limestone. It has been used at the Fay brickyard for making fire and ornamental building brick.

A sample of this clay had the following characters: Color light gray, with occasional yellow to red iron stains. Texture massive, compact, rather hard (1.5 to 2.0), coarse-grained, uniform. Slacked readily and completely into one-fiftieth to one-eighth of an inch granules. Taste, rather lean. Pyrite was not noticeable. When ground

to 20-mesh and mixed with 16.0 per cent of water it made a plastic paste that shrunk 6.0 per cent in drying and 4.5 per cent when burned to vitrification, giving a total shrinkage of 10.5 per cent. Briquettes of the air-dried mud gave an average tensile strength of 143, and maximum of 165 pounds to the square inch. Incipient vitrification occurred at 2,050° F., complete at 2,250°, and viscous at 2,450°. It dried rapidly but needed slow heating to avoid checking.

An analysis gave the following results:

	Per cent.
Silica	61.22
Alumina	25.17
Combined water	8.14
Moisture	1.66
Sesquioxide of iron	1.42
Lime	0.30
Magnesia	trace
Alkalies	1 88
Total	99.85
Total fluxing impurities	3.66
Specific gravity	2 49

Adjoining the Fay land on the north is the Clark pottery which uses this fireclay for the manufacture of stoneware.

Other Deposits. On the east side of Hominy creek, over 12 feet of fireclay are exposed about 25 feet above the creek level. The clay rests on 5 to 6 feet of conglomerate, beneath which is a gray, massive limestone. The clay is very hard and scarcely plastic. The same fireclay also shows on the road to Fulton, about one and one-half miles east of Columbia. Five miles southeast of the town, on the Fulton gravel road, the fireclay shows for two feet in the bank of a small branch 100 feet south of the road. As the Burlington limestone outcrops in the immediate vicinity at from 10 to 20 feet higher than the clay, this is probably a local pocket. About one-quarter of a mile east of the last exposure, or five and a quarter miles southeast of Columbia, on the Henderson farm, fireclay is exposed in the bank of a creek. It is a very hard, massive, plastic, very dark to green clay, with occasional iron stains; it rests on 5 feet of conglomerate, beneath which is the Burlington limestone.

One mile west of Steven's store, on the bank of Cedar creek, from 3 to 5 feet of gray fireclay are exposed, resting on 10 feet of conglomerate at the creek level.

MONROE COUNTY.

Monroe county is more or less covered by the coal measures, especially in the more elevated portions. They are thin and are frequently entirely removed by erosion, which has resulted in exposing the underlying lower Carboniferous limestones. Fireclay usually rests immediately over the ferruginous sandstone at the base of the coal measures. In the neighborhood of Stoutsville a seam is frequently exposed at or near the crests of the hills, and has been utilized by the local stoneware potteries to a small extent. Some of these clays are very refractory, notably the hard, lean clay of the Williamson tract, which is one of the most refractory clays known. Thus far the fireclay has not been used for refractory purposes, as there are no firebrick works in the county, and it has not been shipped to distant factories. While erosion has frequently removed the seams so as to interrupt their continuity over large areas, it is likely that energetic prospecting would find local, undisturbed deposits that would justify working, as regards quality and thickness. In prospecting for fireclay it will be found at or immediately above the horizon of the ferruginous sandstone, which in this county is coarse, brown and micaceous.

CLAPPER.

Williamson Clay Pit. About three miles west of Clapper near the Dannenhauer and Winder stoneware pottery (Tp. 56 N., R. IX W., Sec. 34) is the Williamson clay bank. It rests on the flank of a gentle ravine, through which runs a small dry branch. The clay has been used at the pottery for making jugs and crocks. It is covered by 1 to 4 feet of soil and drift, which is stripped off in working the fireclay, which latter ranges from 5 to 8 feet in thickness and has been irregularly dug over a distance of about 300 feet. Toward the western end of the deposit the clay changes from a hard, lean, coarse, plastic clay to a non-plastic flint clay. Pebbles of rounded flint and sandstone occur in the lower portion of both the plastic and flint clays, and they both seem to rest on flint bowlders and sandstone. The deposit varies from non-plastic to plastic without sharp lines of demarkation. It is one of the most refractory clays known, and is certainly the most refractory in Missouri. A sample of soft plastic clay that was collected here gave the following characteristics: Color light gray, with occasional red and yellow iron stains. Texture massive, compact, hard (2.0 to 2.5), and coarse-grained. Taste, lean to fat, some very sandy. Slacked readily and completely into one-fiftieth to one-tenth of an inch granules. Pyrite was not noticeable. When ground to 20-mesh and

mixed with 15.0 per cent of water it made a plastic paste that shrunk 5.0 per cent in drying and 5.0 per cent when vitrified, giving a total shrinkage of 10.0 per cent. Briquettes of the air-dried mud gave an average tensile strength of 92, and a maximum of 109 pounds to the square inch. Incipient vitrification occurred at 2,200° F., complete at 2,400°, and viscous at 2,600° F. It dried readily and heated without checking.

An analysis gave the following results:

	Per cent.
Silica	70.30
Alumina	20.35
Combined water	7.12
Moisture	0.79
Sesquioxide of iron	0.15
Lime	0.67
Magnesia	0.33
Alkalies	0.49
Total	100.20
Total fluxing impurities	1.64
Specific gravity	2.48

A sample of the non-plastic clay that was collected about 300 feet east of the previously mentioned sample gave the following: Color light gray, with occasional yellow iron stains. Texture massive, compact, hard (2.0 to 2.5), coarse-grained and mixed with more or less coarse sand. Taste, very lean and sandy. Slacked slightly into coarse lumps. Pyrite was not noticeable. When ground to 20-mesh and mixed with 14.0 per cent of water it made a very short or lean paste that shrunk 3.8 per cent in drying and 1.5 per cent when burned, giving a total shrinkage of 5.3 per cent. Briquettes of the air-dried mud gave an average tensile strength of 33, and a maximum of 39 pounds to the square inch. Incipient vitrification occurred at 2,500° F., complete at 2,700°, and viscous above 2,700°. It dried rapidly and heated without checking.

An analysis gave the following results:

	Per cent.
Silica	67.76
Alumina	21.96
Combined water	7.80
Moisture	0.43
Sesquioxide of iron	0.69
Lime	0.96
Magnesia	0.24
Alkalies	0.24
Total	100.08
Total fluxing impurities	2.13
Specific gravity	2.45

This sample is the one in which incipient vitrification occurs at the extremely high temperature of 2,700° F., which statement can be made only of this one clay for the entire state of Missouri.

Other Deposits. Fireclays occur in a number of places in the vicinity; about one mile west of the Williamson pit, on the Gerry place; four miles southwest of the Williamson pit, on the Field land; about 5 miles southwest of the same on the Hardwick land; on the Sharp farm, about two miles north; on the Hart farm, about 2½ miles west of the Williamson pit; and on the Randall land, where 7 to 8 feet of white plastic fireclay were found in digging a well. The latter is a fine, very plastic, light gray clay of apparently excellent quality. It has been used with fair results at the Williamson pottery in making stoneware.

STOUTSVILLE

Half a mile north of Stoutsville (Tp. 55 N., R. IX W., Sec. 15) on the Sponsler land a white to light gray fireclay outcrops in a ravine about 1,000 feet northwest of the house; five feet have been exposed with the bottom still in clay.

On the Woodson farm, about half a mile southeast of Stoutsville, ten feet of very light gray plastic clay were found in digging a well. About 500 feet east of this, on the bank of a small branch, a cropping of flint clay occurs, but its quality and thickness have not been tested. A light gray plastic clay is also stated to occur on the Painter farm about two miles east of Stoutsville.

About two and one-half miles west of Stoutsville, on the Paris road, is the old abandoned Conrad pottery, and adjoining is a deposit of fireclay that is from 2 to 15 feet in thickness. Four feet of drift or glacial clay rest upon it. The fireclay was washed before it was used at the pottery for stoneware. It is mined on a royalty of 25 cents a ton, and it is an excellent potters' clay, and is probably a good fireclay.

Near Goss, there is a dark gray to drab, lean to fat fireclay bed 8 feet in thickness, in a creek bed in the northwest quarter of section 29 (Tp. 55 N., R. IX W.) that appears to be a good fireclay.

North of Paris there is said to be fireclay on the Moxey farm; also another deposit one mile east; and another one mile west.

SHELBY COUNTY.

This county contains outlying basins of the coal measures, in the southeastern portion, while the eastern edge of the western coal basin occurs on the western side. The central and northern portions consist of limestone of the lower Carboniferous series. Excellent fireclay occurs at Lakenan and the same seam is liable to be found in the

eastern and southeastern portions of the county. The fireclay seam occurs in the more elevated areas as the drainage courses have eroded through the coal measures into the underlying limestones. The quality of the fireclay is usually excellent.

- *Huggins Pit.* Three-quarters of a mile south of Lakenan, and adjoining the Monroe county line, is the fireclay pit of A. F. Huggins. There are two seams ; an upper one which is 6 feet thick, and a lower one which is five feet thick, while between them are 2½ feet of soft, yellow sandy shale. Both of these fireclays are used at the Huggins pottery for making stoneware and crocks. They occur at the base of the coal measures, and a 12-inch seam of coal is associated.

A sample gave the following characteristics : Color variable, from light to dark gray, to yellowish brown. Texture massive, compact, hard (2.0 to 2.5), fine-grained, and uniform. Taste, somewhat fat. Slacked readily and completely into one-fiftieth to one-tenth of an inch granules. When ground to 20-mesh and mixed with 17.5 per cent water it made a decidedly plastic paste that shrunk 7.5 per cent in drying and 4.8 per cent when vitrified, giving a total shrinkage of 12.3 per cent. Briquettes of the air-dried mud gave an average tensile strength of 160, and a maximum of 180 pounds to the square inch. Incipient vitrification occurred at 2,000° F., complete at 2,200°, and viscous above 2,500°. It dried rapidly and heated without cracking.

An analysis gave :

	Per cent.
Silica	67.60
Alumina	18.97
Combined water	10.03
Moisture	1.42
Sesquioxide of iron	1.25
Lime	0.20
Magnesia	trace
Alkalies	0.96
Total	100.83
Total fluxing impurities	2.41
Specific gravity	2.38

A sample of the lower seam had the following characters : Color dark gray, with occasional brown iron stains. Texture coarsely lamelar, hard (1.5 to 2.0), coarse-grained and uniform. Taste, lean and gritty. Slacked rapidly and completely into granules and some flakes of one-fiftieth to one-tenth of an inch in size. Pyrite was not noticeable. When ground to 20-mesh and mixed with 17.0 per cent of water it made a plastic paste that shrunk 6.2 per cent in drying and 4.2 per cent when vitrified, giving a total shrinkage of 10.4 per cent. Briquettes of the air-dried mud gave an average tensile strength of 144, and a maximum of 167 pounds to the square inch. Incipient vitrification

occurred at 2,200° F., complete at 2,400°, and viscous above 2,600°. It dried rapidly and heated without checking. When burned to vitrification it gave a compact tough body. It is well adapted for stoneware and refractory purposes.

A chemical analysis gave:

	Per cent.
Silica	58.80
Alumina	30.50
Combined water	6.74
Moisture	0.40
Sesquioxide of iron	2.34
Lime	1.20
Magnesia	0.51
Alkalies	0.30
Total	100.50
Total fluxing impurities	4.85
Specific gravity	2.41

There occur 5 feet of fireclay under a 24-inch seam of coal at the Barker pit, about two miles north of Shelbina, on a branch of the North fork of Salt river. A hand sample collected from the dump shows that it is a dark gray to black, massive, rather hard, coarse to fine-grained, fat, sandy fireclay. As it contains some carbonate of lime it is hardly likely to be very refractory.

MORGAN COUNTY.

Morgan county is covered by the rocks of the Ordovician age and is therefore devoid of the continuous beds of fireclay that are likely to occur in the coal measure-covered areas. There are local pockets or basin deposits of kaolin, flint clay, and fireclay, which, while individually of a limited extent, may prove to be more abundant than is suspected. Thus far only one kaolin pocket has been found, but several flint clay deposits have been discovered in the neighborhood of Versailles, and one pocket of plastic fireclay has been found, though its extent has not been determined. While the latter is of excellent quality it is not favorably located for cheap shipping at present on account of the long railroad haul that is necessary to reach the markets. In the future, however, it is likely to become of greater value, when a market is established nearer home.

VERSAILLES.

South of Versailles, one mile, on the land of E. A. Crewson, a sample was collected from a small pit on the flank of a hill near the Versailles medical spring. It appears to be a local pocket or deposit in a small basin of coal measures, as black shale is found in the immediate vicinity over 12 feet in thickness, through which seeps the water that is found in the medical spring. Insufficient work has been done

to determine the magnitude of the deposit and the place is too distant from the present firebrick factories to bear the shipment. The quality, however, is excellent, and being a plastic or bond clay, it would be very valuable to use in connection with the extremely refractory flint clays that are found in the immediate vicinity. While the deposit is not likely to extend over a large area it is doubtless of sufficient size to justify the erection of a local plant, which would be well situated with reference to raw material.

A sample collected gave the following characteristics: Color very light gray, with occasional yellow to brown iron stains. Texture massive, very compact, uniform, soft, and very sandy. Taste, plastic and gritty. Slacked very slowly and imperfectly into one-fortieth to one-fourth of an inch granules. Pyrite was not noticeable. When ground to 20-mesh and mixed with 16.0 per cent of water it made a rather plastic paste that shrunk 5.3 per cent on drying and 4.0 per cent when vitrified, giving a total shrinkage of 9.3 per cent. Briquettes of the air-dried mud gave an average tensile strength of 90, and maximum of 98 pounds to the square inch. Incipient vitrification occurred at 2,200° F., complete at 2,400°, and viscous above 2,700°. It dried rapidly, but required slow heating to avoid checking. It burned to a creamy gray color and a compact tough body when vitrified. It is well adapted for either stoneware or refractory purposes.

An analysis gave the following results:

	Per cent.
Silica	68.94
Alumina	21.18
Water	7.08
Sesquioxide of iron	0.78
Lime	0 61
Magnesia	0.43
Alkalies	0.66
Total	99.68
Total fluxing impurities	2.48
Specific gravity	2.83

STODDARD COUNTY.

About one mile south of Dexter, on the east flank of Crowley ridge, is a brown-colored clay that is used by the Dexter pottery for stoneware, which proves on trial to be refractory. A sample from the Kirkpatrick land (Tp. 25 N., R. X E., Sec. 27, NE. qr) gave the following characteristics: Color very light gray with slight yellow to brown iron stains. Texture massive, compact, soft (1.0 to 1.5), fine-grained and uniform. Taste, smooth and fat. Slacked rapidly and completely into one-thirtieth to one-fourth of an inch granules. Pyrite was not noticeable. When ground to 20-mesh and mixed with 20.0 per cent of

water it made a decidedly plastic paste that shrunk 7.8 per cent on drying and 4.0 per cent when vitrified, giving a total shrinkage of 11.8 per cent. Briquettes of the air-dried mud gave an average tensile strength of 138, and maximum of 168 pounds to the square inch. Incipient vitrification occurred at 2,000° F., complete at 2,250°, and viscous at 2,600°. It burned to a decided pink color when soft-burned, and dark gray when hard-burned, with a strong body. It is well adapted for stoneware and refractory purposes, though it is not excessively refractory.

An analysis gave the following:

	Per cent.
Silica	68.50
Alumina	20.81
Water	7.62
Sesquioxide of iron	1.79
Lime	0.77
Magnesia	trace
Alkalies	0 53
Total	100.02
Total fluxing impurities	3.09
Specific gravity	2.13

THE FIRECLAY INDUSTRY.

At the present time the manufacture of fire-brick and other refractory ware in Missouri is principally carried on at St. Louis where there are seven plants, five of which are of large capacity. This concentration of the industry in St. Louis is primarily due to the thick seam of excellent fireclay that crops out so near the surface and which it is very cheaply mined. This, combined with a good home market, cheap fuel and unexcelled shipping facilities, has resulted in such a growth and development of the industry that the city is one of the largest manufacturing points in the country for this class of goods. There are plants at Mexico, Vandalia and Fulton in northern Missouri, of which each has the advantage of excellent fireclay, but lacks the advantage of a home market and extensive shipping facilities. There is also a small local plant at Crystal City in eastern Missouri that is run in conjunction with the Plate Glass works at that place. The total capital invested in the 12 fire-brick plants is $1,150,000 and the annual value of the output is $900,000 to $1,000,000.

ST. LOUIS DISTRICT.

The first effort in making fire-brick in St. Louis is said to date back fifty years when a small plant was erected on the Gravois road, near Meramec street. The oldest of the present plants was established by Richard Howe, in 1855, which has since gradually grown to

A FIRE BRICK PLANT; EVENS & HOWARD—CHELTENHAM.

the present large establishment of Evens and Howard. In the same year a Mr. Hamilton also started a yard which prospered until his death, when he was succeeded by James Green, the present president of the Laclede Fire Brick Co. Under the latter's able management the company has prospered and developed into one of the largest plants in the country. The Mitchell Clay Co. started to make roofing tile about 1866, but after five years effort, in which it was found that it was ahead of the times, it went into the manufacture of refractory material, which has continued on a moderate scale until the present day. The Parker-Russel Mining and Manufacturing Co. began experimenting in 1866, and three years later erected a small factory which has grown into the present large plant. The Missouri Fire Brick Co. began the manufacture of terra cotta lumber in 1881; but not finding this a success it began the manufacture of firebrick which has been continued to the present day. Coffin and Co. had a large plant at Pittsburg, Pa., to supply the glass trade with crucibles and glass-pots, and in 1884 built a large branch establishment in north St. Louis. Since the failure of the company in 1892, it has been operated by the Mississippi Glass Co. for the manufacture of firebrick and glass-pots. Since then no further increase has occurred in the number of plants devoted to the manufacture of refractory materials, though some of the older ones have grown to very great magnitude.

The firebrick factories depend primarily on the basal fireclay seam of the lower coal measures that has been designated as the Cheltenham seam, and which is a plastic clay of superior quality. When goods of exceptional fire-resisting qualities are desired it is mixed with more or less white flint clay that is shipped in over the Wabash, and the St. Louis and San Francisco railroads from points 50 to 100 miles west. The average cost of the St. Louis clay delivered at the factory is from \$.60 to \$1.00 a ton for the run of the mine; this makes it one of the cheapest markets for crude material in the country.

At all the factories firebrick is made by the soft mud process by hand. The crude clay is tempered with water and more or less grog or crushed firebrick, to a thin paste; it is then moulded by a crew of two men and three to five boys as off-bearers, at the rate of 4,000 a crew. The bricks are slowly dried, on either racks or by drying floors by the aid of heat from steam pipes and are edged and turned as often as may be necessary to secure uniform drying. Before they are completely dry they are usually repressed to secure uniformity in size and perfect shape. The standard kiln that is used for burning is the round, downdraft, bee-hive pattern which varies from 15 to 30 feet in diame-

ter. The bricks are burned exclusively with coal, requiring from three to four days for water-smoking, from two to three days for burning, and from two to three days more for cooling. As the clay stands rapid cooling without checking, the wicket or door is usually thrown open, to hasten the cooling, after the fires are burned out. Within the past few years, different machines have been tried to supersede the hand method, with varying success. In no case do the bricks meet with the confidence of the hand made, or command as high a price.

Attempts made with the dry processes have not succeeded, but with the semi-dry process the results have been more favorable. The clay is always mixed with more or less grog, cement or lean material for which the favorite article is old burned fireclay or firebrick. Usually from twenty-five to thirty per cent of grog is employed for the standard brick mixture, which makes a brick of great strength, yet with pores enough to dry and burn well and stand the heat. For large tiles and blocks, a larger percentage of grog is required, or up to forty to sixty per cent, which of course weakens the strength of the ware by thus reducing the amount of bonding material.

The market for St. Louis firebrick extends throughout the entire southern country, east as far as Ohio, north as far as Canada, and west to the Pacific coast. Nearly all the output is shipped away, since the closing down of the iron furnaces and steel mills in the state, the home demand has been greatly reduced. The St. Louis market is one of the cheapest in the country as an excellent quality of firebrick sells for $12.00 to $16.00 a 1,000, and special brands from $18.00 to $25.00. All the numerous shapes demanded in furnace construction are made in St. Louis, and extensive stocks are carried by the large factories. The central location of St. Louis, and its unexcelled shipping facilities by rail and water, enable the manufacturers to cover a very wide territory and one that is constantly growing in its consumption of refractory goods.

Evens and Howard Plant. This firebrick factory (plate XV) is located at Cheltenham in the western part of St. Louis, between the tracks of the Missouri Pacific and the St. Louis and San Francisco railroads. It has fireclay mines to the north and south sides that are less than half a mile away. Firebrick, retorts, furnace blocks and other refractory goods are manufactured. It also has a very extensive department for the manufacture of sewer-pipe, in which two steam presses are used. The company is now capitalized at $400,000, of which about one-half is devoted to the sewer-pipe department. The output is equivalent to 3,000,000 to 4,500,000 brick a year.

The firebrick plant is located in a large separate building (four stories), that is surrounded by a special line of kilns, which are all of the down-draft pattern. They are 32 in number of which 10 are used for the refractory department. The firebricks are manufactured by the soft-mud process, in hand presses. The clay is crushed and tempered in wet-pans, of which there are four. In tempering, from 15.0 to 20.0 per cent of water is employed, which makes a plastic, easily moulded paste that is conveyed to tables by an overhead system of iron rails, and is worked by a press crew into standard size brick at the rate of 3,000 a day for each crew. After moulding, the brick are slightly dried on a brick floor, which is heated by a system of overhead steampipes. When the brick have dried sufficiently to be very stiff and firm, they are repressed, and again returned to the floor for complete drying, during which they are edged and turned to secure uniformity in drying. "Grog" that consists of crushed burnt material is added to the extent of 20.0 to 60.0 per cent, according to the sizes and uses of the ware. Old bats and worn out firebrick are employed for this purpose, besides calcined flint clay, from the interior of the state. Large blocks and tiles are moulded by hand, and are very slowly and carefully dried, to avoid checking and cracking from irregular shrinkage. Three grades of firebrick are made according to the service to which they are to be subjected, which range in price from $14.00 to $40.00 a 1,000. Recently an attempt was made to make firebrick by the dry and semi-dry methods, with a dry-press machine, but as the quality of the brick was not satisfactory it was abandoned.

Laclede Plant. The factory of the Laclede Fire Brick Co., which is one of the largest in the United States, is located on the south side of the St. Louis and San Francisco railroad at Cheltenham, in west St. Louis, with private switches to both this and the Missouri Pacific tracks. The company started in a very small way in 1855, under the management of Mr. Hamilton, and has grown until now it has a capital of $500,000, and a surplus of $150,000. Its annual output is valued at $600,000, of which, however, about 70 per cent is represented by the output of the sewerpipe department.

The brick are made by the soft-mud process by hand, and also recently by the semi-dry process with a dry press; usually two-thirds plastic Cheltenham fireclay and one-third grog or ground firebrick are employed. The clay is ground in dry-pans, and is tempered in pugmills with 15 to 20 per cent of water, to soft mud. Besides the manufacture of firebrick and furnace blocks, gas retorts are extensively made, for which there are special rectangular kilns with large doors. There are 26 kilns, of which 20 are devoted to the sewerpipe depart-

ment. The company has its own fireclay mine in the rear of the factory, where the fireclay seam averages 7 feet in thickness. Clays are also bought entensively from the other Cheltenham mines. Flint clays from along the Wabash and the St. Louis and San Francisco railroad are also largely used for the very refractory grades of firebrick.

Parker-Russel Plant. The Parker-Russel Mining and Manufacturing company has a plant locating on the Morganford road in the southern portion of St. Louis and connected by a private switch to the Oak Hill branch of the Missouri Pacific railroad. Experimenting began in 1866 with fireclay which was found under a coal seam that has been worked extensively for the local St. Louis market. Three years later, a small factory was erected, which has since been enlarged to the present plant. The company now has a capital of $150,000, which is exclusively devoted to the manufacture of refractory ware. It manufactures firebrick, furnace blocks, gas retorts and fire proofing, for which 20 down-draught kilns are employed.

The firebrick are made by the soft-mud process. After crushing and grinding the clay in dry-pans, it is tempered in a pug-mill. For tempering the clay for gas retorts, the wet-pan is employed, as it gives more uniform and reliable temper. Most of the firebrick and furnace blocks are made in a hand press, for which two crews are employed. An augur machine has been recently introduced of 10,000 daily capacity to manufacture by stiff-mud process. For the manufacture of gas retorts, a special moulding machine is employed, and a very carefully prepared soft mud is used. As many as 1,500 retorts are made per annum, which are shipped all over the country, especially to the East. The company has an extensive fireclay mine underlying the plant and also purchases fireclay from the other Cheltenham mines. Flint clay for grog, is obtained from points on the Wabash and the St. Louis and San Francisco railroads.

Mitchell Plant. The Mitchell Clay Manufacturing Co. is situated on Manchester road at Cheltenham, within one block of the Missouri Pacific and the St. Louis and San Francisco railroads. The plant was originally started as a roofing tile factory in 1870, but as it did not prove a financial success, the manufacture of firebrick was undertaken two years later, and continued ever since. The company owns two acres of clay land in the rear of its premises, but at present is buying its clay in the open market, which is delivered at the factory for 70 cents a ton for run of the mine. The plant is equipped with an 8-foot dry-pan, in which the clay is crushed and is then tempered in two pug-mills 5 feet long. The brick are made in hand presses, and are burned in four, round, down-draft kilns, that vary from 10 to 16 feet in diameter.

Draintile was formerly made on a Tiffany augur machine, but was discontinued as the business was unimportant. The capital stock is $20,000 and the annual output is from 1,200,000 to 1,500,000 firebricks.

Missouri Plant. The Missouri Fire Brick company is located between the Missouri Pacific and the St. Louis and San Francisco railroads, at Cheltenham. It started in 1881 to manufacture buff brick and terra cotta lumber, but after a brief and unsatisfactory season the manufacture of firebrick and furnace blocks was undertaked and since continued. The plant is equipped with one 9-foot dry-pan, and a pug mill for tempering the clay. The brick are made exclusively on hand presses, dried on a drying floor, and burned in four, round, down-draft kilns that vary from 10 to 25 feet in diameter. The company formerly operated its own mine, which was just south of the works; but since this was cut off by the construction of the St. Louis and San Francisco railroad, the clay has been bought in the open market. The capital of the company is $25,000, and the annual output is about 2, 500,000 bricks.

Coffin Plant. The plant of Thomas Coffin and Co. is located at the foot of Ferry street, on the Wabash railroad, in the northern part of St. Louis. It was started in 1884, with a capital of $200,000, as a branch of the extensive glass-pot works of the same firm at Pittsburgh, Pa. The principal business is the manufacture of glass-pots and tank-blocks for the various demands of the glass trade; firebrick are also made. The clay employed for the glass-pots is washed potclay that is obtained at the company's mine at Gratiot station in the extreme southwestern portion of the city. This is mixed with imported German pot-clay (Gros-Almarode), together with a liberal amount of "grog" or old ground-up glass-pots that have been carefully freed from glass. The clay is ground in dry-pans of which there are two, is then tempered in two wet-pans, and finally very carefully and thoroughly tempered by heel treading and spading, after which it is stored in bins to "ripen" for sometime before it is used.

Since the failure of Coffin and Co., in 1890, the plant has been operated by the Mississippi Glass Co., the works of which adjoin the plant. In addition to carrying on the manufacture of glass-pots, it has put in a Lyon press, and is making firebrick by the semi-dry process at the rate of 17,000 a day, besides making 4,000 mud brick on a hand press, three pots, and ten tons of furnace blocks. There are seven round, down-draft kilns, of 32,000 capacity each.

Christy Plant. The Christy Fireclay Co, is situated on the Morganford and Gravois roads and is connected by a private switch with the Oak Hill branch of the Missouri Pacific railroad. The company started

shipping crude or lump and washed pot-clay as early as 1862, which was the exclusive business until 1887, when the washing department was greatly enlarged, and the manufacture of firebrick was inaugurated. Since then the plant has rapidly grown, and is to-day a larger producer of firebrick, furnace blocks, washed and crude pot clay. The capital stock is $200,000, and the value of annual output (the greater portion of which is clay) is said to be about $200,000. The washing department is equipped with three agitators, washers or blungers that are about 4 feet deep by 12 feet in diameter, in which the clay is mixed with water to a thin cream, while the coarse sand, pyrite and other heavy impurities settle to the bottom. The cream is run through a fine sieve, to remove any sand or coarse material, then remixed in a fourth blunger and allowed to settle to a thick paste in large wooden tanks lined with sheeting. The water is finally extracted by pumping it through a large filtering press, from whence the washed clay, as a stiff mud is run into blocks by an augur machine after which it is dried in racks. The blocks of washed clay are sold in both the raw and calcined condition. In the furnace-block department the washed clay is mixed with a grog consisting of burnt washed clay, which is pugged several times, and then heel-trodden before final moulding into blocks to secure perfect tempering. There are seven down-draft kilns and a cupola calciner for flint clays. In the fire-brick department, the brick are made on a Johnson press, which is an English semi-dry machine and then burned in the Johnson continuous kiln. This kiln has 14 chambers of 28,000 capacity each, and is provided with a stack 95 feet high in order to secure a good draft. The kiln is fired entirely from the top with crushed Pittsburg coal and about half a ton of coal is required for each 1,000 bricks.

JEFFERSON COUNTY.

Crystal Plate Glass Company. The glass-pot and furnace-block department of the Crystal Plate Glass Co., at Crystal City, Jefferson county, furnishes the pots or crucibles and blocks for the furnaces of this very large glass plant. Pot, shell, or old glass pots that have been carefully freed from glass, are used for grog, and the pots are stored from three to six months before they are used. There is one circular down-draft kiln for burning the furnace blocks, but the firebrick are purchased in St. Louis.

CALLAWAY COUNTY.

Fulton Plant. The Fulton Fire Brick and Mining Company is located near the station at Fulton, on the Jefferson City branch of the Chicago, Alton and St. Louis railroad. It has a capital stock of $75,-000. The plant was erected in 1885. Firebrick, firetile and furnace-blocks are manufactured and dry milled clay. The value of the annual product is about $60,000. The plant is equipped with one 8-foot dry-pan, one 7-foot wet-pan, and one plunger tile machine. The brick are made by the soft-mud process on a handpress, and four crews are employed, who are paid $1.75 a 1,000 for moulding and are required to make 3,000 a shift. The local Fulton fireclay is mainly used, which is very refractory. The plant is provided with six round, and one square down-draft kilns of 60,000 capacity and a cupola calcining furnace, for taking the shrinkage out of the clay that is used for grog. If the bricks are under-burned, they are white to pale cream in color, and when exposed to the weather they become yellow to green-stained, from an efflorescence of the iron salts. It requires three days to water-smoke, from three to four days for strong firing, and three days for cooling.

AUDRAIN COUNTY.

Salamander Plant. The Salamandar Fire Brick Co. is located at Vandalia on the Chicago, Alton and St. Louis railroad about half a mile west of the station. It was started in 1883, as the Audrain Manufacturing and Coal Mining Co., which ran intermittently in mining clay and coal, manufacturing firebrick to a limited extent, until 1890, when the name was changed to the Vandalia Fire Brick Co. In March, 1892, it was leased and operated under the name of the Salamander Fire Brick Co. The fireclay is obtained from a large vein directly beneath the works. The plant is equipped with a Frost 9-foot wet-pan, one calcining cupola of 20 tons daily capacity, and four, round, down-draft kilns of 10,000 to 45,000 capacity. The plant is run by a 60-horse-power engine and boiler. The firebrick are manufactured by the soft-mud process on hand-presses, which with some furnace blocks, comprise the output.

Mexico Plant. The Mexico Fire Brick Co. is located on the Wabash and the Chicago, Alton and St. Louis railroads, near the new union station. It was erected in 1889 and was burned down in 1892, but was rebuilt. The plant is equipped with one dry-pan, two wet-pans, and a three-mould Boyd semi-dry press. The firebrick are made by the semi-dry process, on the Boyd machines, which has a capacity of 20,000

a day and by the soft-mud process on hand presses. The machine-made brick are satisfactory in shape and uniformity, but do not inspire confidence, for which reason they bring a much lower price than the hand-made brick from the same clay. There are six, round, down-draft kilns of 15,000 to 40,000 capacity, three rectangular down-draft kilns of 15,000 to 100,000 capacity and one calcining cupola of 20 tons daily capacity. The "Empire" brand of firebrick in several grades are made, as well as furnace blocks and shapes. A considerable amount of milled fireclay is shipped. The value of the output 1891 was $78,000.

Western Stove Lining Company. This is a small plant in the city of Mexico, for the manufacture of specialties, as linings. It was started in 1891. It is equipped with one round, down-draft kiln of 20,000 capacity, and the output in 1891 was about 700 tons of stove linings. valued at $14,000.

Statistics of Fire Brick Works in Missouri.

Name.	Town.	County.	Capital stock.	Began.	Engine.	Boiler.	Kilns.	Product, 1891.
Christy Clay Co	Oak Hill....	St. Louis city	$200,000	1862	1	2	9	$200,000
Coffin and Co	Bremen	St. Louis "	200,000	1884	1	1	7	
Evens and Howard..	Cheltenham	St. Louis "	150,000	1855	......	...	30	120,000
Laclede Fire Brick Co	Cheltenham.	St. Louis "	175,000	1855	2	8	24	210,000
Missouri Fire Brick Co	Cheltenham.	St. Louis "	25,000	1881	1	1	4	88,000
Mitchel Clay Mfg. Co	Cheltenham.	St. Lou's "	20,000	1872	1	1	4	21,000
Parker-Russell Mfg. Co	Oak Hill.....	St. Louis "	150,000	1866	1	....	20	144,000
Crystal Plate Glass Co......	Crystal City.	Jefferson....	20,000	......	1	1	1	10,000
Fulton Fire Brick Co	Fulton.......	Callaway....	75,000	1885	1	1	7	60,000
Western Stove Lining Co...	Mexico	Audrain	10,000	1891	1	1	1	14,000
Mexico Fire Brick Co.	Mexico	Audrain	75,000	1889	2	3	9	78,000
Salamander Fire Brick Co .	Vandalia	Audrain	50,000	1883	1	1	4	50,000
Totals	....	....	$1,150,000	.....	.....	....	120	$945,000

CHAPTER XI.

POTTERS' OR STONEWARE CLAYS.

The term "potters' clay" is a broad name that covers a considerable range of clays, but as generally used it has no well defined meaning, except that a plastic clay is always understood. The usual idea that is conveyed by the term potters' clay is a plastic clay that is too fusible for refractory purposes, and which answers for making stoneware, the better grades of earthenware, terra cotta and sometimes sewerpipe. It is not usually supposed to possess the large amount of iron necessary to make red terra cotta or good building brick, nor to be sufficiently fusible for paving-brick. The term is also applied to "ball clays," or the high-grade white-burning clays that are used for "C. C." ware, ironstone china and decorated ware, and it is occasionally applied to plastic fireclays. The sense in which it is here employed is to cover those clays that are not sufficiently refractory for firebrick, and that do not possess sufficient iron and other impurities to be used for red brick, or paving brick, and which are favorable for stoneware, buff brick, light colored terra cotta and light colored earthenware. The term potters' clay is not infrequently and narrowly limited to stoneware clays.

By the term stoneware is meant the common earthenware that is made very extensively throughout the state and is used for jugs, milk-crocks, fruit-jars and similar domestic utensils. It is usually light buff in color and is burned to a semi-hard body. When burned to incipient vitrification it is strong and slightly porous, so that it requires either a salt or slip glaze to render it impervious to liquids. The true fireclays or highly refractory clays are occasionally used for this purpose in this state, notably in Monroe county, but in the great majority of cases the clays are a special class by themselves that are appropriately denominated potters' clays, and which are not sufficiently refractory to be true fireclays, though otherwise they are very similar to them in their general physical and chemical properties. They are occasionally known by the name of "bastard" fireclays," in allusion to their close resemblance to the true fireclay except in lacking in refractoriness. At least one point is always understood as an es-

at moderate speed without the employment of grog, (7) tough and strong body when burned, (8) free from carbonates, sulphates, or other salts that are liable to cause blisters in burning.

An eminent degree of plasticity is demanded in order that the clay may be easily moulded and turned into the thin walls of the vessel on the potters' wheel, and yet retain its shape perfectly until burnt.

The clay should be free from coarse particles of any kind as these produce spots and blemishes on the surface of the ware that make it unsalable, except at unrenumerative figures. As most clays are more or less contaminated with coarse sand, nodules of iron, minerals, particles of feldspar and similar detrimental granules, they generally require a preliminary washing, which not only satisfactorily frees the clay from these objections, but also insures a very important requisite in the sale of the ware in giving it uniformity of tint or color. Very few clays are sufficiently pure to be worked directly from the bank into stoneware and the majority require more or less careful washing before moulding. In Missouri the washing is usually performed in crude, home-made outfits, which while satisfactory in the quality of work, are slow, and expensive in putting the clay into a workable condition. None of the potteries are equipped with blungers and filter presses for accomplishing this within a few hours, which is necessary in the operation of a modern plant, to obtain quick results and a low cost of washing.

The iron in stoneware clay should be low, especially if it is to be salt-glazed, as a light-colored body is greatly preferred by the trade; hence only a small amount of iron is permissible, and this should be in a uniformly disseminated condition. Local occurrences of iron produce spotting and discoloring that greatly affect the sale of the ware, though washing may largely modify, if not entirely eliminate, this objection. If the iron is present in the usual form of pyrite crystals ("sulphur," "mundic," "brasses," or "shiners") it is readily eliminated by washing and unless it is thus removed the crystals make ugly spots when the ware is burnt. If the ware is slip-gazed and the iron is present in a uniform disseminated condition, as oxide or silicate, it is not so objectionable, and it is likely to make a stronger ware; but the body is dark, and such goods do not sell as readily as the lighter colored ware. This is an inherited fetish that is not justifiable, but is one of those ugly facts that it is unwise for the business man to attempt to correct.

The ware should be burned to an incipient vitrified body, which is necessary to give it strength and render it much less porous. The

heat to accomplish this should be easily obtained in a kiln with common fuel and hence this temperature should not exceed 2,200° F., and preferably less than 2,000° F., for the lower this temperature the easier it is to obtain and the less the fuel required. If the ware is not completely vitrified, it is very porous, soft and more or less lacking in strength and makes an inferior quality of goods, even though rendered impervious by salt or slip-glazing.

There should be a range of at least 200° F., between the points of incipient and complete vitrification, as it is undesirable to pass beyond the latter point in this class of goods, since the color then becomes glassy, and the ware is almost sure to be more or less brittle. As it is almost impossible to control a kiln within a smaller range than 200°, the burner should have at least this margin, and preferably 300°, to safely insure the burning of the entire kiln to a close strong, well-burned ware, and yet not render it glassy and brittle, or allow the shape of the ware to be lost.

An important commercial point in the running of a pottery is the ability to rapidly dry the ware without its checking or cracking, as the longer time it takes requires not only a larger plant and a larger stock, but occasions a much greater risk of breakage, while the ware is in the tender condition of drying. This feature is not always appreciated, and local clays are often used that require the greatest care in drying or heating to avoid checking or cracking which adds appreciably to the expense. It pays to send much further away for a clay that will stand rapid heating and drying that to submit to the loss, expense and time involved in using clay that requires a low and careful drying. There is such a marked difference in clays and in this respect, which can only be determined by actual trial, that no new clay should ever be decided upon until this important point has been determined by practical tests. An ideal potters' clay can be placed direct from the potters' wheel in the sun, or wind, or steam-heated in a drying room without checking, yet many clays used in potteries would crack to pieces if dried so rapidly.

The thinness of the ware, smoothness of the surface, and strength demanded, prevent the employment of grog, which would otherwise expedite the drying and render it much safer, as is done in the fire-brick trade. The service to which stoneware is subjected demands material that can stand rough usage and carry heavy loads without breaking. The clay must, therefore, burn to a tough, strong body, but this is usually the case, if properly burned, with a clay that is sufficiently plastic to readily mould into stoneware. If the clay-burner uses a sufficiently high temperature to secure this strength but few

clays will be lacking in this requisite if they can be readily moulded. It is for this reason that a stoneware clay should vitrify at a temperature readily obtained in ordinary potters' kilns as the fireclays or highly refractory clays need too much heat in order to attain the strength demanded in this class of goods.

A pure clay or kaolinite never causes blisters, blebs, pimples, or other eruptions on the surface of the ware, unless due to the introduction of air in tempering, which latter is due to carelessness in working the clay. If sulphates, carbonates, or other salts that give out gases at high temperatures are present they are liable to bloat or blister the ware, which is so serious a defect as to render the goods unsalable. This danger can only be safely determined by actual trial, which should never be omitted before adopting a new untried clay.

PHYSICAL PROPERTIES.

The plasticity required of a satisfactory working stoneware clay is such that it should work freely in the hand with water to a rather soft paste, without cracking. It should be what clay-workers term "fat," to mould readily. As determined by the tensile strength method of arriving at the absolute value of plasticity, it should have a tensile strength of at least 100 pounds to the square inch, and preferably over 150 pounds, when the clay is worked into a briquette as stiff mud and broken in a testing machine after drying. The best potters' clay of Missouri show a tensile strength as high as 160 to 200 pounds to the square inch and occasionally as high as 250 pounds (Commerce clay). The only objection to this very marked plasticity is that it is liable to entail slow drying or heating to avoid checking or cracking, as such eminent plasticity means almost invariably a very fine clay, and the finer the clay the greater the risk there is of checking and cracking, unless very slowly dried, heated and cooled after burning. The amount of water required to render stoneware clays sufficiently plastic to be readily moulded varies from 20.0 to 25.0 per cent. The shrinkage that results in drying the stoneware clays is somewhat excessive, on account of the large amount of water required, and ranges from 6.5 to 10.5 per cent, and averages 7.5 per cent. The additional shrinkage that results when the dried ware is burned varies greatly with the particular clay, and ranges from 4.0 to 8.5 per cent, averaging about 4.5 per cent, which gives a total shrinkage of 10.0 to 18.0 per cent and an average of 12.0 per cent.

The point of incipient vitrification, or the temperature to which a clay should be raised to give a good strong close body ranges in Missouri stoneware clays from 1,600° to 2,200° F., and is usually between

1,900° and 2,000°, while the point of complete vitrification is usually 200° to 300° higher, beyond which the clay should never be heated, as it loses its shape and begins to swell or bloat.

CHEMICAL PROPERTIES.

As plasticity is one of the first requisites of potters' or stoneware clays, they are usually rather high in alumina, and not very high in silica, though there are many exceptions. In most cases, except the flint clays, the higher in alumina, the more plastic is a clay, while the higher the silica the less plastic it is, but as mentioned under "Plasticity," the condition of the kaolinite particles whether they are coarsely laminated, or very finely scaly has such a marked influence as to make this chemical generalization of very moderate value. The alumina usually ranges from 22.0 to 32.0 per cent though occasionally it goes as low as 13.0 per cent and as high as 36.0 per cent. The silica shows a much greater range, as in excellent potters' clays it is found to vary from 50.0 to 77.0 per cent, though usually from 55.0 to 70.0 per cent. If the clay is sufficiently plastic to mould readily, which really depends upon the development of a fine plate structure of the kaolin particles, the higher the silica the better, if in a finely divided condition, as it enables the ware to be rapidly dried and heated without checking, and decreases both the air and fire-shrinkages, while it does not decrease the strength of the ware to an objectionable degree, if the clay is eminently plastic.

If clay is high in alumina the chemically combined water is necessarily high, and conversely if the clay is high in silica, it is always low in water, hence typical stoneware clays generally are rather high in combined water, ranging from 5.0 to 12.0 per cent, and averaging 8.0 to 10.0 per cent. The less the water in a stoneware clay the better, as the fire-shrinkage is less, hence the risk of checking in burning is reduced; also the less the iron the better, as it gives a lighter color. Excellent potters' clays in Missouri that burn to a light buff color have from 1.0 to 5 0 per cent of oxide of iron, but it is generally necessary, when it exceeds 2.5 per cent to eliminate a portion by washing. The condition of the iron has a very important influence on the amount that is permissible. If occurring in the more usual forms of crystals of pyrite, concretions of limonite, or nodules of siderite or the carbonate, it is necessary to remove it by washing, even though present in small amounts, as it causes black, more or less slag-like spots. When present in a uniformly disseminated condition as oxide or silicate it is very much less objectionable, as it then gives a general

yellow to red to brown color to the body, which though not desirable, can be largely masked by slip-clay glazes.

Lime in potters' clays is advantageous if in combination as silicate, as it renders the clay more fusible and tends to lighten the color. If present in the form of carbonate in not excessive amounts and the ware is well burned, it is not objectionable if in a finely disseminated condition. If present in the form of sulphate or gypsum crystals, it causes blisters and blebs, from its decomposition into sulpuric acid vapors when the slip or glaze is in a soft condition. If the lime is not present as sulphate, or as nodules or concretions of carbonate it may exceed 5.0 per cent, though in the Missouri stoneware clays it is usually found to range from 0.3 to 2.0 per cent. Magnesia present in the form of carbonate, and in a finely divided condition is not objectionable. If present as sulphate it is very detrimental, as it causes blisters as in the case of sulphate of lime. Magnesia is not usually present in larger amounts than 2.0 per cent, and it generally ranges between 0.3 and 1.5 per cent. The alkalies are very desirable as they render the clay more fusible, thereby making it easier to burn to a strong, close body, and they give a wide range between the points of incipient and complete vitrification. The amount in the Missouri samples ranges from 0.5 to 4.5 per cent, and averages about 2.5 per cent. Titanic acid is probably present to a slight extent in all stoneware clays, for as mentioned in the chapter on the "Origin of Clays" it is almost invariably present in the rocks from which the clays are primarily derived. It does not usually exceed 2.0 per cent and as this is insufficient to produce any coloring action its presence is generally of no importance to the potter. If it were present in large amounts it would tend to produce a blue to purple color in the ware when hard-burned.

The salient points in the chemistry of the potters' clays are low iron (to obtain which, it may be necessary to wash all the clay), high alkalies, and an absence of sulphates.

GEOLOGICAL HORIZONS OF STONEWARE CLAYS.

The stoneware clays of Missouri occur principally in four geological formations (1) in pockets in the paleozoic limestones in the southern half of the state; (2) as seams of so-called fireclay in the coal measures, in the northwestern half of the state; (3) as beds in the Tertiary of the southeastern corner of the state; and (4) as local beds or pockets in the glacial drift in the northern portion of the state.

1. The potters' clays of the first class, or pockets in the paleozoic limestones of the southern half of the state, are always very local and of limited extent and are identical in their origin with the flint clay

and kaolin pockets that have been previously described. These are accumulations in sink-holes and other depressions in the limestones and originate from the chemical dissolution of the surrounding limestones and the local accumulation of the insoluble matter, or sand and clay. When the accumulation is very pure, especially if subjected to subsequent chemical action, it forms the pockets of flint clay, but if the deposits are less pure, and not consolidated or changed by chemical action into a non-plastic condition, it forms the potters' clay; and when formed *in situ*, it gives the kaolins if pure, or the residual clays if impure. The class of residual clays have thus far been sought only when pure enough for white-ware, or the ball clays and kaolins, or when sufficiently refractory to answer for fire-brick, as in the flint clays. There are many deposits that are too impure to answer for these purposes but which are well adapted for stoneware, that will undoubtedly be developed, when the demand justifies their exploration. As the tonnage required for a stoneware pottery is not large, the limited dimensions of these pockets is not such a serious drawback as in the case of fireclay, where large quantities are usually necessary; and while it would not be good judgment to erect a plant upon the basis of one pocket, unless it had been thoroughly explored and proved to be of exceptional magnitude, the presence of one pocket is strongly indicative of the occurrence of others in the immediate neighborhood. This class of deposits will undoubtedly become of much greater importance in the future, and will be found of a very satisfactory nature both physically and chemically for the demands of stoneware. They occur almost exclusively south of the Missouri river in the great limestone area, as they are buried under the glacial and coal measure deposits in the northern and western portions of the state. They are not confined to any one particular horizon, as they occur from the lower Carboniferous down to the Cambrian. The purer limestones of the Burlington (lower Carboniferous) and Trenton are the most favorable for the occurrence of these deposits, but they are found throughout the entire paleozoic series.

2. The horizon at which the most reliable, persistent, and largest deposits of stoneware clays occur is in the coal measures, where many of the so-called fireclay seams and some shale beds are suitable. The coal measure series have thus far proved the richest, which is also true of the refractory clays. Henry county, in the western part of the state which is on the edge of the coal basin, contains the most extensive development of stoneware clay, and in consequence considerable clay is shipped to a number of potteries in the western

and southern portions of the state and to Kansas. The so-called fireclays of the barren coal measures are usually impure and consequently too fusible, prone to blister, and to give a dark colored body after burning. The true fireclays are occasionally used for stoneware. The shales, especially if weathered as at the outcrop, are used for stoneware if the percentage of iron is not too great, as they are found to be very satisfactory about drying and burning rapidly without checking. When a shale has not weathered into a soft, plastic condition, it requires grinding to render it plastic. The Missouri potteries are not equipped to perform this. The shale must be sufficiently pure, as it must be used direct without washing, as the washing of a shale, unless well weathered, is extremely imperfect and unsatisfactory, being usually attended with such a heavy loss as to make it unprofitable. By selecting the pure seams of the shale beds, this class of deposits could undoubtedly be very much more largely used, and they are well worthy of the attention and consideration of potters. Most of the potteries in Missouri obtain their supplies from either the so-called fireclays, or weathered shales of the coal measures.

3. In the Tertiary area in the extreme southeastern portion of the state, there is a great deal of clay that is admirably adapted for stoneware purposes, and which supplies the local potteries. One of these clays is noteworthy, the Commerce clay, as it has a deep pink color and contains 72.0 per cent of silica; it is an exceptionally good potters' clay, as it can be used without washing, and it burns to a light buff body as the pink color is apparently due to organic matter. The magnitude of these beds and their accessibility make them the most promising in the state, as soon as the conditions for marketing them improve. At present the local markets are small, and the shipping facilities are not the best; but for a base of operations for building up an extensive shipping trade into the southwestern country, Arkansas, Texas and Oklahoma it is extremely promising and well worthy of the attention of capitalists.

4. The glacial deposits that cover that part of the state lying north of the Missouri river occasionally contain beds of clay that are suitable for stoneware purposes. A serious objection to the glacial deposits is their unreliability in quality and quantity, as they are liable to suddenly change into very impure clays, or worse still, suddenly change into mere seams or die out entirely. They need to be very carefully tested and verified both as to their quality and extent before basing operations upon a given deposit, but many of them will justify the erection of extensive plants if this precaution is taken. They vary greatly as to their accessibility, sometimes being near the

surface and again being covered with a heavy burden of ferruginous sands and clays that render their working quite expensive on account of the stripping.

The total tonnage consumed by the stoneware potteries probably does not exceed 10,000 tons a year, valued at $7,500, though it is difficult to form a reliable estimate from the total absence of records in the case of many of the small potteries. None of the stoneware clays are shipped out of the state except from Henry county, which sends 500 to 1,000 tons a year to Kansas and Texas.

THE DEPOSITS OF STONEWARE CLAYS.

AUDRAIN COUNTY.

The coal measures that cover the greater portion of Audrain county contain beds of clay and shale that are more or less satisfactory for stoneware. The fireclays that are worked at Vandalia and Mexico could be used for this purpose, though they are so refractory that it would require a very high degree of heat to obtain a close strong body. Some of the purer shales are likely to be more satisfactory for this reason, which at or near the outcrop, will be plastic enough to mould readily, but grinding will be necessary to reduce the hard shale to a plastic mass. While none of these are being used at present active prospecting would disclose suitable deposits.

ADAIR COUNTY.

About six miles west of Kirksville, in the valley of the Chariton river, potters' clay occurs on the Lutz place (Tp. 62 N., R. XVI W., Sec. 16, NE. qr.) and at several other places in the vicinity. It is three feet thick and white in color, though intermixed with some greenish yellow to red clay. It is underlain by limestone, and is said to have been used at one time for stoneware.

At the Penn coal mine, at Danforth, on the Quincy, Omaha and Kansas City railroad, there are 2 to 5 feet of so-called fireclay under the coal seam that is worked at this place, at a depth of 45 feet. No samples were tested from this deposit, but its thickness renders it worthy of investigation, as it is more likely, if usable, to be a stoneware clay, rather than a refractory or genuine fireclay. At the drift of the Penn mine at Stahl, on the same railroad, there are 2 feet of so-called fireclay under the coal seam. This seam of clay may be too fusible for refractory purposes, but it may answer for stoneware.

BARRY COUNTY.

Potters' clay occurs within two miles of Monett, that has been used in the Purdy stoneware pottery at Pierce City.

BARTON COUNTY.

The greater portion of Barton county is covered by the coal measures and as they contain several so-called fireclay seams, beside a number of shale beds, there is considerable material available in this county for stoneware purposes. The clays and shales are liable to be exposed in the ravines cut by the streams, while shafts of moderate depth would expose one or more workable seams in almost any part of the district. Washing is generally necessary to give the most satisfactory results.

A shaft sunk by Jacob Cornwall, of Golden City, in the most southerly of the Golden City group of mounds, disclosed under 14 inches of coal a seam of clay eight feet thick, that could probably be used for making stoneware. About 4 miles south of Lamar, on the Waltman land, is a seam of gray potters' clay three feet thick, that is favorable for stoneware. The following is the section at this place:

		Feet.
7.	Sandstone, shaly	8
6.	Shale, black	1
5.	Coal	1
4.	Clay, potters' (sample)	3
3.	Shale	7
2.	Shale, dark blue	7
1.	Coal	1

The sample of this clay collected gave the following characteristics: Color light gray, with numerous superficial brown iron stains. Texture massive, compact, rather hard (2.0), fine-grained and uniform. Taste, lean and finely gritty. Slacked slowly and perfectly into coarse granules one-tenth to one-half inch in size. Pyrite was not noticeable; mica was present as very fine scales to a slight extent; it contained a few plants; hydrochloric acid caused no effervescence. When ground to 20-mesh and mixed with 19.0 per cent of water is made a somewhat lean paste that shrunk 5.5 per cent in drying and 6.0 per cent when vitrified, giving a total shrinkage of 11.5 per cent. Briquettes of the air-dried mud gave an average tensile strength of 87, and a maximum of 98 pounds to the square inch. Incipient vitrification occurred at 2,000° F., complete at 2,200°, and viscous above 2,400°. It dried readily and heated without checking. It burned to a light cream to gray, compact, tough body when vitrified, It is an excellent quality of stoneware clay.

An analysis gave the following results:

	Per cent.
Silica	65.32
Alumina	22.68
Water	7.42
Sesquioxide of iron	1.81
Lime	0.25
Magnesia	0.67
Alkalies	1.72
Total	99.82
Total fluxing impurities	4.45
Specific gravity	2.46

At the old Lamar pottery, 4 miles southeast of Lamar (Tp. 30 N., R. XXXI W., Sec. 18, NE. qr.) a bed of gray shale is used. It is six feet thick and occurs nearly at a depth of ten feet.

At the Wear shaft No. 1, one and one-half miles west of Minden is the following section:

	Feet.
5. Clay, yellow	12
4. Sandstone, coarse, shaly	2
3. Shale, sandy, yellow	25
2. Coal (the seam worked)	2
1. Clay, potters'	5

A sample of the clay taken from the sump of the shaft showed the following characteristics: Color dark gray, somewhat stained yellow and brown by iron. Texture massive, slightly lamellar, compact, hard (2.0 to 2.5), mostly fine-grained, with small concretions. Slacked rapidly and completely into fine grains one-sixtieth to one-twentieth of an inch in size. Taste rather lean and somewhat sandy. Pyrite and mica were not noticeable, but the clay effervesced slightly with hot acid, and the concretions very freely when warm, indicating that they were carbonate of iron. When ground to 20-mesh and mixed with 19.0 per cent of water it made a very plastic paste that shrunk 7.5 per cent in drying and 4.0 per cent when vitrified, giving a total shrinkage of 11.5 per cent. Briquettes of the air-dried mud gave an average tensile strength of 187, and a maximum of 203 pounds to the square inch. Incipient vitrification occurred at 1,700°F., complete at 1,850°, and viscous above 2,000°. It dried rapidly and heated without checking, and burned to a tough, compact, gray body that was freely mottled brown to black with iron, when vitrified.

An analysis gave the following results :

	Per cent.
Silica	50.94
Alumina	24 24
Water and carbonic acid	11.58
Protoxide of iron	7.18
Lime	0 95
Magnesia	1.60
Alkalies	3 60
Total	100.09
Total fluxing impurities	13.33
Specific gravity	2.54

BATES COUNTY.

Bates county is entirely underlain by the coal measures, and it therefore has several beds of shale, and contains more than one seam of so-called fireclay under the coal veins. The so-called fireclay is not sufficiently refractory for firebrick purposes. At Rich Hill in the four coal shafts and three slopes, there are usually from two to four feet of the fireclay under the coal seam. It has a dark gray to black color, is very coarse-grained and is very sandy, with fine pyrite crystals. It would require washing before it could be used for stoneware and it is probably too coarse to make a fine grade of ware.

BOONE COUNTY.

As the coal measures cover the greater part of Boone county, there are seams of so-called fireclay and perhaps some pure shales that are suitable for stoneware. One such fireclay seam has been utilized at Columbia, and there are others of similar character. A clay, in the coal measures, occurs about two miles east of Columbia, near the Fay brickyard, that has been used for making stoneware and for which it is favorably adapted. As this clay has already been described, no further reference need be given here.

BUTLER COUNTY.

There is more or less potters' clay in the neighborhood of Poplar Bluff that has been used by the local potteries for making stoneware, draintile, and flower-pots. It proved very unsatisfactory for stoneware, but seemed favorable for the latter purposes. The clay is said to be very sandy, and red to brown in color. At the Craven pottery, at Poplar Bluff, there are about two feet of fat, red, very sandy clay that is used. It is overlain by a gravel and sand bed that is three feet or more in thickness, but the clay is too irregular and too impure to be suitable for stoneware.

CALDWELL COUNTY.

The greater portion of Caldwell county is covered by the barren coal measures. These contain a few so-called fireclay seams or shales that are pure enough for stoneware, but by deeper working purer and better beds may be reached under the coal seams. At Hamilton and Kingston a clay occurs that appears favorable, but in the absence of tests no statement can be made as to its value. At the Tom Creek shaft, about two miles southeast of Hamilton, there is a seam of fireclay twelve feet thick under the coal that is operated at a depth of 300 feet. At the Caldwell shaft, two miles east of Hamilton, there is a seam of about three feet of so-called fireclay at a depth of 365 feet. It is a fine, gray, soft, uniform clay, with no carbonate of lime and seems favorable for stoneware.

At the Kingston coal shaft, one mile north of the town of Kingston, a seam of so-called fireclay four feet thick occurs under the coal bed that is worked at a depth of 350 feet. A sample of this clay that was collected gave the following characteristics: Color uniform gray. Texture massive, compact, rather hard (2.0 to 2.5), uniform, fine-grained. Taste, fat. Slaked rather slowly but completely into one-fiftieth to one-tenth of an inch grains. Pyrite was not noticeable; but occasionally fossil leaves were seen; it was not affected by hydrochloric acid. When ground to 20-mesh and mixed with 24.0 per cent of water it made a very plastic paste that shrunk 11.0 per cent in drying and 4.0 per cent when vitrified, giving a total shrinkage of 15.0 per cent. Briquettes of the air-dried mud gave an average tensile strength of 199, and maximum of 263 pounds to the square inch. Incipient vitrification occurred at 1,600° F., complete at 1,750,° viscous above 1,900.° It required to be very slowly dried to avoid checking, but heated more rapidly. It burned to a tough, compact, brown, vitrified body. This clay vitrifies at such a low temperature that it requires great care in burning, while on account of its exceptional strength it is liable to go to pieces in drying unless performed very slowly.

CALLAWAY COUNTY.

About one-eighth of a mile north of Fulton there are 5 feet of grayish potters' clay in the railroad cut; it is badly stained yellow by iron and contains more or less gravel and sand so that it is necessary to wash it for stoneware purposes.

About one-half mile southeast of Guthrie, on the King farm, 14 feet of clay are said to have been struck at a depth of 8 feet in sink-

ing a well. On the Reynolds place (Tp. 46 N., R. X W., Sec. 18) near the railroad, 5 feet of gray plastic clay were passed through in digging a well. On the Lyons land (Tp. 46 N., R. X W., Sec. 20, NW. qr.) is a seam of soft, plastic potters' clay 2 feet thick that contains occasional crystals of selenite. A sample that was collected gave the following characteristics: Color light gray, very liberally spotted with red and yellow iron stains. Texture massive, soft, very fine-grained and uniform. Taste, fat and slightly sandy. Slacked slowly and imperfectly into granules one-twentieth to one-fourth of an inch in size. Pyrite and mica were not noticeable, but coarse grains of white sand were abundant. When ground to 20-mesh and mixed with 21.6 per cent of water it made a plastic paste that shrunk 6.9 per cent in drying and 9.1 per cent when vitrified, making a total shrinkage of 16.0 per cent. Briquettes of the air-dried mud gave an average tensile strength of 89, and a maximum of 113 pounds to the square inch. Incipient vitrification occurred at 1,900° F., complete at 2,100°, and viscous above 2,300°. It dried rapidly, but required to be slowly heated to avoid checking. It burned to a compact, tough, brown body when vitrified.

A chemical analysis gave the following results:

	Per cent.
Silica	48 92
Alumina	32.90
Water	13.58
Sesquioxide of iron	3.10
Lime	0.40
Magnesia	0 37
Alkalies	0 82
Total	100.09
Total fluxing impurities	4.69
Specific gravity	2.13

On washing ten pounds of this clay there was a loss of four per cent and a noticeable improvement in the quality as shown by the following results: When ground to 20-mesh and mixed with 16.0 per cent of water it made a plastic paste that shrunk 6.4 per cent in drying and 8.4 per cent when vitrified, making a total shrinkage of 14.8 per cent. Briquettes of the air-dried mud gave an average tensile strength of 71, and a maximum of 101 pounds to the square inch. Incipient vitrification occurred at 2,000° F., complete at 2,200°, viscous above 2,400°. It dried rapidly, but was heated very slowly to avoid checking. It burned to a brown, tough, vitrified body.

An analysis gave the following:

	Per cent.
Silica	47.13
Alumina	34.98
Water	13.88
Sesquioxide of iron	2.92
Lime	0.37
Magnesia	0.32
Alkalies	0.52
Total	100.12
Total fluxing impurities	3.76

On the Dennison farm, at New Bloomfield, 8 feet of white potters' clay were encountered in boring a well. About three-fourths of a mile northeast of New Bloomfield, where the Jefferson City road crosses a small branch flowing over the Burlington limestone, a gray to red or brown potters' clay shows for 100 feet, about 5 feet above the creek. It contains nodules, concretions and seams of hard red hematite, to eliminate which it would be necessary to wash the clay.

CAMDEN COUNTY.

Three miles northeast of Decaturville (Tp. 37 N., R. XVII W., Sec. 36, NW. qr.) in Chief Field Hollow, there is a bluish, sandy, fine, plastic potters' clay that is about three feet thick. It is evidently a weathered outcrop of a shale bed, as it is surrounded by the Silurian limestone. It contains pockets of ochereous clay, and occasionally gypsum crystals, so that it would require washing before it could be used for stoneware. Five miles west of the town on a small branch on the west side of Bank creek, on the Winterburn place, over one foot of soft, fine, bluish plastic clay that is heavily stained yellow by iron is exposed above the bank of the branch. As it is surrounded by limestone on all sides and is probably the weathered outcrop of a ferruginous shale.

CAPE GIRARDEAU COUNTY.

Cape Girardeau is famous for its superior quality of ball clay or kaolin that is suitable for white-ware. It occurs as pockets that are evidently local accumulations from the adjacent limestones, as the basal limestone in this district is generally very pure. Most of the pockets furnish a clay of very superior quality that is suitable for white-ware, but in some instances, they are not sufficiently pure for that purpose, but would answer for stoneware and the coarser varieties of earthenware. A few such occurrences are mentioned below, and there are undoubtedly many others. At present there is no local demand for these clays as they do not bear the expense of

shipping to distant markets, so that there has been no inducement to prospect for them.

Northwest of Cape Girardeau about three miles, on Juden creek, there are about five feet of plastic potters' clay on the Sterbern farm. Five miles northwest of the town (Tp. 31 N., R. XIV E., Sec. 21) on the bank of a small creek is, according to Shumard, a deposit of yellow potters' clay. According to the same authority there are four feet of nearly white potters' clay on Morgan land in section 12. Three miles west of Cape Girardeau, and half a mile south of the Jackson pike, on the Claproth land, is a deposit of red to white plastic clay that is said to have been used for saggers in the old white-ware pottery at Cape Girardeau. It lies at the base of a small hill, but as it had not been operated for several years a satisfactory sample could not be obtained.

CARROLL COUNTY.

Carroll county is underlain by the coal measures. It contains beds of so-called fireclay and shales that are likely to be suitable for stoneware and other coarse pottery purposes and the statements subsequently given should in no way suggest the limited occurrence of this class of clays. Active prospecting would undoubtedly disclose numerous workable beds, when there is a demand for this class of clays. About one-fourth mile west of the Wabash station at Dewitt are seven feet of potters' clay under 20 feet of loess, in the face of a bluff. The clay is a drab yellow color and is very plastic. One mile west of the town on the Griffith land (Tp. 53 N., R. XXI W., Sec. 22, SW. qr.) are two to seven feet of so-called fireclay that is suitable for stoneware. This bed is said to thicken to 20 feet.

CASS COUNTY.

Cass county is underlain by coal measures that belong both to the barren series and the lower or productive series, the latter occurring in the southeastern portion of the district. Some of the so-called fireclays that occur in these formations are suitable for stoneware purposes, and one of these seams has thus been utilized at Harrisonville. Some of the numerous shale beds that characterize this formation are also sufficiently pure to prove satisfactory for pottery purposes. The southeastern portion of the county where the lower coal measures occur, is more liable to be productive of clays and shales suitable for stoneware purposes than other portions. On the western side of Harrisonville, on the flank of the hill rising from the Kansas City, Fort Scott and Memphis station the following section is exposed:

		Feet.
6.	Limestone, gray to brown, compact, with crinoid stems	4
5.	Shale, soft gray	5
4.	Potters' clay	3
3.	Shale, sandy, yellow	2
2.	Limestone, compact, gray, fossiliferous	4
1.	Shale, sandy	25

The seam of potters' clay is undoubtedly the same that outcrops on the Grand river, four miles further west, that is subsequently described, though it is at least 100 feet higher at its outcrop on the flank of Harrisonville. The clay is somewhat shaly, and is said to have been used in a small pottery that was operated here several years ago. The seam of clay not only extends to the Grand river, where it is well exposed as shown in the section, but is reached in wells six miles west of the town. About four miles west of Harrisonville the following section is exposed on the bank of Grand river, where it is spanned by the county iron bridge:

		Feet.
8.	Soil	½
7	Gravel	¼
6.	Clay, brown, joint	1
5.	Shale, soft, rather sandy, yellow to brown	8
4.	Shale, soft, fat, dark drab	5
3.	Potters' clay	3
2.	Shale, sandy, yellow	5
1.	Shale, sandy, green to yellow, with siderite concretions (exposed to bed of river)	10

A sample of this clay gave the following characteristics: Color light to dark greenish gray to drab, with occasional yellow streaks of iron. Texture somewhat shaly, soft (1.5 to 2.0), and mostly fine-grained, with some coarse sand. Taste, fat to sandy, in the greenish portion. Slacked readily and completely into one-eightieth to one-twentieth of an inch granules. Pyrite was not noticeable, while mica was sparingly present. When ground to 20-mesh and mixed with 20.0 per cent of water it made a very plastic mass that shrunk 7.5 per cent in drying and 4.5 per cent when vitrified, giving a total shrinkage of 12.0 per cent. Briquettes of the air-dried mud gave an average tensile strength of 246, and a maximum of 270 pounds to the square inch. Incipient vitrification occurred at 1,700° F., complete at 1,900°, and viscous at 2,100°. The clay required rather careful drying and heating to avoid checking and cracking.

An analysis gave:

	Per cent.
Silica	63.93
Alumina	19.73
Water	7.53
Sesquioxide of iron	3.69
Lime	0 53
Magnesia	0 21
Alkalies	3 40
Total	100.02
Total fluxing impurities	8.83
Specific gravity	2.34

On washing ten pounds of this clay with distilled water, and sifting through an 80-mesh sieve a residue was left of 3½ ounces or 2.2 per cent, which consisted mainly of sand and ferruginous matter that ranged from one-twentieth to one-eighth of an inch in size. When this washed clay was mixed with 20.0 per cent of water it made a very plastic paste that shrunk 8.0 per cent in drying and 5.0 per cent when vitrified, giving a total shrinkage of 13.0 per cent. Briquettes of the air-dried mud gave an average tensile strength of 230, and a maximum of 265 pounds to the square inch. Incipient vitrification occurred at 1,750° F., complete at 1,900°, and viscous above 2,150°. It burned to a red to brown, strong, compact body when vitrified and dried and heated rather rapidly without checking.

An analysis gave the following results:

	Per cent.
Silica	64.62
Alumina	19.98
Water	7.42
Sesquioxide of iron	2 91
Lime	0.44
Magnesia	1.31
Alkalies	3.25
Total	99.98
Total fluxing impurities	7.91

CHARITON COUNTY.

Chariton county is underlain with the coal measures, excepting the extreme southern portion, where limestones of the lower Carboniferous age are exposed in the bluffs of the streams. In the coal measures occur seams of so-called fireclay and occasional beds of shale that are likely to answer for stoneware purposes. Near Brunswick is a bed of greenish potters' clay seven feet thick (Tp. 53 N., R. XX W., Sec. 3, SW. qr.) This clay was used in 1888 and subsequently in a small stoneware pottery at this place. Further up the branch on which this was found in another thin seam of potters' clay.

CLARK COUNTY.

Clark county is underlain by the coal measures in the western and northern portions. There therefore occur in this area seams of so-called fireclay, and beds of shale that will answer for stoneware purposes. A heavy mantle of drift renders prospecting tedious and expensive, which probably largely accounts for the few occurrences of potters' clays that are known in this district, but thorough prospecting would disclose good deposits. Potters' clay occurs two miles northeast of Kahoka on the Sherwood land (Tp. 65 N., R. VIII W., Sec. 2, NE. qr.) On the forks of Fox creek about four miles south of Kahoka, three or four feet of potters' clay occur under shale. On the bank of Fox creek a gray, hard, rather lean, compact fireclay occurs in the southeast quarter of section 1 (Tp. 65 N., R. VIII W.) The following is the section:

	Feet.
Shale, black	5
Coal	1
Fireclay	4
Shale	2
Sandstone, (ferruginous)	10

Fireclay apparently of good quality also occurs under the dark shale in the southwest quarter section 32 (Tp. 67 N., R. VIII W.)

COLE COUNTY.

Cole county is south of the great coal basin, and contains very few stratified beds of fireclay, potters' clay, or shales that are suitable for stoneware purposes. The formations consist essentially of limestone that are largely magnesian. There are however a number of small outlying pockets of coal, most of which are underlain by fireclay. Silicious clay stone of light color is said to occur in the magnesian limestone in the hills of Little Tarcon creek a short distance from its mouth. Samples of clay were examined that were said to occur two miles from Elston. Some of it is suitable for stoneware, while other portions are badly mixed with sand, suggesting that the material might be greatly lacking in uniformity.

COOPER COUNTY.

Cooper county is immediately south of the coal basin; it is therefor devoid of regular beds of potters' clay, but contains small local pockets or outliers of the coal measures. These outliers are often sufficient to furnish large quantities of clay and they are well worthy of thorough investigation. These outliers usually occur on the northern border of the county.

The Boonville potteries at present get clay from Calhoun, in Henry county, which is of a very superior quality for stoneware. Formerly it was obtained from the vicinity of Boonville, or from one to two miles east, and from two to five miles south. Four miles southwest of Boonville and one-fourth mile north of the Missouri, Kansas and Texas railroad is the Weber coal mine and clay pit. The clay is light gray with more or less yellow stains, plastic, and seems quite well adapted for stoneware, though somewhat sandy in places; it needs washing to free it from sand and gravel. The deposit is at least four feet thick and is said to be from 6 to 10 feet. It lies from 3 to 5 feet below the surface in a gentle rolling country and is mined and delivered in Boonville for $1.75 a ton. About one mile south of Boonville, on the new county road, is the Smith coal mine that enters Channelside hill. The air shaft exposed the following section:

		Feet.
6.	Loess and yellow clay	18
5.	Limestone, compact, gray	1
4.	Shale, black	6
3.	Shale, soft gray	4
2.	Coal	1¼
1.	Fireclay (exposed)	3

The fireclay is very fine, plastic, with some yellow iron stains and tastes slightly of alum. At the old Smith mine about three-fourths of a mile south of Boonville there is said to have been from 10 to 12 feet of potters' clay overlying the coal seam, but it is more likely that it was shale that has weathered into a plastic clay. Four miles west of Boonville, on the Missouri Pacific railroad is an interesting pocket of cannel coal that is operated by the Missouri Valley Coal Mining Company. This is a local pocket or old basin in the limestone that appears to have accumulated a deposit of coal. The largest of several small coal pockets here is 300 feet long by 150 feet wide, with 40 feet of coal at the thickest point, which is at a depth of 80 feet. The coal is underlain by from 2 to 5 feet of fireclay which is highly pyritic, and also tastes of alum. It is gray to greenish in color, and by selection and washing it would doubtless answer for stoneware purposes.

DADE COUNTY.

Dade county is underlain by a few local pockets of the coal measures in the central part of the county and by the edge of the Missouri and Kansas coal basin in the northwestern portion of the district, where it occupies the hills and elevated portions of the land, as the valleys are eroded to the underlying Carboniferous limestones. Cedar township has the largest area of this thin margin of the basal coal measures. There is a thin coal vein that is usually two feet in thickness, under

which is a seam of fireclay that is sometimes as thick as six feet. The fireclay seam in places may be favorable for stoneware, and possibly refractory purposes. At the Sharp mine where the clay is 30 feet below the summit of a hill, and where the coal seam has been worked by drifting and stripping in the depressions, the following section occurs:

		Feet.
4.	Sandstone	5
3.	Shale, dark arenaceous	10
2.	Coal	$2\frac{1}{2}$
1.	Fireclay	6

Its distance from the railroad prevents the development of this clay, but the thickness of the seam renders it worthy of investigation should circumstances render it available for the market.

DENT COUNTY.

Limestones and sandstones of the Silurian underlie most of the district. They occasionally carry beds of shale that possibly may be satisfactory for stoneware. Several indications show the probable occurrence of clays suitable for stoneware in this county, notably in the railroad cut of the St. Louis, Salem and Little Rock railroad 500 feet north of the Salem station, at the Sligo iron bank two and one-half miles east of Sligo Furnace, and on the Strong farm two and one-half miles east of Gladden. The indications were excellent at each of these places for workable bodies of good clay. The clay deposit at the Sligo bank is a large lenticular mass that was met with in sinking to the underlying iron ore, and the clay passed through by the shaft was ferruginous; it strongly indicates the probable occurrence of similar large pockets of possibly greater purity. There are no potteries in this county to stimulate prospecting, or any inducement to search for deposits of clay.

FRANKLIN COUNTY.

In this district there are rich deposits of flint fireclay, which weathers occasionally at the outcrop into soft plastic clays that are used for stoneware, but they are better adapted for whiteware. Such deposits occur at the Buck and Whitson bank, near Union, which has been described under "China clays." There are other deposits of clay near Washington which have been described under "Fireclays." They have also been used for stoneware and other purposes, but as they are more valuable for refractory purposes reference should be made to the above places for detailed accounts of these deposits.

GREENE COUNTY.

According to Professor Shepard, who has made a special study of this county, the following section is to be seen at a shaft 30 feet deep that was sunk on the Kelso farm four miles west of Willard (Tp. 30 N., R. XXIII W., Sec. 20, SW. qr.):

		Feet.
6.	Soil, with red clay and chert	2
5.	Limestone and chert	5
4.	Clay, red to green, varigated	3
3.	Shale, compact, blue, with fossil plants	18
2.	Shale, black, with selenite crystals	4
1.	Shale, black without selenite crystals	3

Several other prospect shafts have been sunk on the same farm, which indicate a large deposit of these shales and clays. A short distance south of the Kelso farm on the Long place are 15 feet of pure white, very plastic clay, which is regarded as unusually promising; it is overlain by two feet of soil, and 35 feet of yellow ochre occurs under it. On the Gilmore farm three miles northwest of Kelso's similar deposits occur, and likewise 15 miles northwest of Springfield, on the Sac river. Two and one-half miles northeast of Buckley valuable clay deposits are also found.

GRUNDY COUNTY.

Grundy county is overlain by productive coal measures, except on the western border, where the barren measures make their appearance. So-called fireclays and shales outcrop in the deep ravines, or in the valleys, or are reached by shafts. The fireclay seam exposed on the bank of Grand river is rather too high in lime to be desirable for stoneware purposes. On the north bank of Grand river, near the iron bridge one mile south of Trenton, is the following section:

		Feet.
6.	Soil and drift	20
5.	Shale, with siderite concretions	8
4.	Shale, dark	15
3.	Coal	½
2.	Potters' clay	8
1.	Limestone	1

A sample of this clay that was collected gave the following characteristics: Color light gray, somewhat stained yellow with iron. Texture massive, rather soft (1.5 to 2.0), and rather coarse-grained, with small concretions of carbonate of lime. Slacked rapidly and completely into one-fortieth to one-twelfth of an inch granules. Taste, rather lean and somewhat sandy. Pyrite was not noticeable; hydrochloric acid caused copious effervescence. When ground to 20-mesh and mixed with 19.0 per cent of water it made a very plastic paste that

shrunk 7.0 per cent in drying and 2.0 per cent when vitrified, giving a total shrinkage of 9.0 per cent. Briquettes of the air-dried mud showed an average tensile strength of 209, and a maximum of 227 pounds to the square inch. Incipient vitrification occurred at 1,750° F., complete at 1,900°, and viscous above 2,000°. It burned to a gray to brown, compact body when vitrified.

HENRY COUNTY.

Henry county is underlain by the coal measures, which contain at least two beds of so-called fireclay, and several beds of shale. The latter are described elsewhere and are used for sewerpipe, paving-brick, and common brick. The so-called fireclay is an excellent grade of potters' clay, being in fact the best found in the state, and it is not only used locally by the potteries at Clinton and Calhoun, but it is shipped to most of the potteries in the western and southwestern parts of Missouri, as well as to Kansas where it is preferred to the local clays. At least one of these seams, the "Calhoun," is sufficiently pure to answer for refractory purposes, as the clay will stand from 2,300° to 2,500° F. before the danger or yielding point is reached. Abundant coal of workable thickness also occurs thus adding greatly to the natural advantages of the county. It is the leading producer of stoneware in the state, as it contains the largest number of potteries, as well as the only large steam pottery. A map of the deposits of Henry county is given on the accompanying plate XVI.

CALHOUN.

Calhoun is the largest shipping point of potters' clay in Missouri, as it produces from 4,000 to 5,000 tons a year, of which one-third is used at the Calhoun potteries. A persistent seam of potters' clay that ranges from 2½ to 4 feet in thickness is found near the crest of the ridges which is an excellent stoneware clay. The amount of overlying stripping is usually moderate so that it is cheaply mined. It is such a safe, easy-working, reliable clay that it is largely used throughout the southwestern portion of the state and at Fort Scott, Kansas. The usual price is about 75 cents a ton, delivered on board cars at Calhoun. While the same seam is worked throughout this district the clay varies somewhat, being harder and leaner in some pits than others. In collecting a sample to represent this district an equal mixture of clay from the Jegglin and from the Hardin pits was taken, which gave the following characteristics: Color dark gray, with slight yellow to brown iron stains. Texture massive, compact, uniform and very fine-grained. Taste, lean and very finely gritty. Slacked rather readily

and completely to one-fortieth to one-tenth of an inch granules. Pyrite was not noticeable. When ground to 20-mesh and mixed with 16.5 per cent of water it made a plastic paste that shrunk 5.5 per cent in drying and 2.2 per cent when vitrified, giving a total shrinkage of 7.7 per cent. Briquettes of the air-dried mud gave an average tensile strength of 150, and a maximum of 168 pounds to the square inch. Incipient vitrification occurred at 2,100° F., complete at 2,300° and viscous above 2,500.° It dried rapidly but required slow heating to avoid checking. It burned to a compact, gray to buff body when vitrified.

An analysis gave the following results:

	Per cent.
Silica	71.94
Alumina	17.60
Water	5.27
Sesquioxide of iron	2.35
Lime	0.62
Magnesia	0.56
Alkalies	1.51
Total	99.85
Total fluxing impurities	5.05
Specific gravity	2.34

Jegglin Clay Pit. About one-fourth mile north of Calhoun is the Jegglin bank of clay from which about 1,500 tons a year are shipped. It has been operated for 12 years on a royalty of 20 cents a ton and the clay is shipped to the Jegglin potteries at Boonville and Calhoun. The clay is an admirable stoneware clay as it takes a salt glaze well, stands rapid drying, gives a light colored ware, and is very safe working. The following is a section exposed at this bank:

		Feet.
7.	Soil	1
6.	Clay, yellow	4
5.	Shale, greenish gray, soft and fat	2
4.	Sandstone, red, soft, coarse-grained	1
3.	Shale, red to black, soft, fat	½
2.	Clay, potters'	4
1	Sandstone, shaly, yellow, coarse-grained (exposed)	1

The potters' clay is hard and massive when freshly mined, seeming to be rock rather than clay; but on exposure to the weather it slacks completely into a soft, plastic mass. It is very sandy and lean, and dark gray in color. There are occasional yellow streaks of iron along the joint planes especially where there is no overlying shale. The overburden is stripped off from the clay, which is then loosened by blasting, and hauled in wagons to the railroad, which is about one-fourth mile distant, for shipping. The clay lies about level, or with very slight roll.

Littlepage Clay Bank. This pit is situated about one-half mile north of Calhoun, and one-fourth mile northwest of the Jegglin old

pit, of which it is undoubtedly a continuation. The clay is similar to that in the Jegglin bank, and it is shipped to the potteries in the southwestern portion of the state, to the extent of 1,000 to 1,200 tons annually. The following is a section at this bank:

	Feet.
7. Soil	1
6. Clay, red, sandstone and gravel	2
5. Sandstone, gray, coarse-grained, friable	1½
4. Sandstone, intermixed with shale	4
3. Shale, drab to green, soft, fat, rich in iron concretions	8
2. Sandstone, very ferruginous	½
1. Clay, potters'	8

The sandstone overlying the potters' clay becomes so ferruginous as to merge into hematite or red iron ore.

Hardins Bank is three-fourths mile north of the town. The clay is overlain by a thin seam of sandstone that merges into iron ore. About 500 feet south of the pit there is a lean ore that will assay 35.0 to 40.0 per cent in iron. This is the same seam as exposed at the Jegglin bank, though the lower portion is so sandy that it is not mined. The following is a section:

	Feet.
6. Soil, sandy	1
5. Clay, brown, joint	2
4. Clay, gray to brown	1
3. Sandstone, ferruginous	1
2. Clay, potters'	8
1. Sandstone, yellow, shaly (exposed)	1

Little Clay Bank. About one mile north of Calhoun is the Little bank, which was opened in 1889. It produces about 1,000 tons of clay a year, which is shipped to southwest Missouri, and as far as Fort Scott, Kansas. The clay is similar to that in the Jegglin bank of which it is an extension. The following is a section at this bank:

	Feet.
5. Soil	1
4. Clay, brown to gray	1
3. Clay, gray (weathered shale)	2
2. Iron ore, sandy (with hematite)	½
1. Clay, potters'	3½

The clay also outcrops on the southeastern edge of several hills, and occurs in the crest of a north and south ridge.

Mullin Clay Pit. One-fourth mile east of Calhoun is a clay bank which has only been a small producer, with a total output to date of perhaps 500 tons. The upper portion of the potters' clay seam at this point is rather fat, dark colored and fine-grained, while the lower portion is very sandy, hard and light gray in color.

LEWIS.

At Lewis station on the Missouri, Kansas and Texas railroad (Tp. 42 N., R. XXV W., Sec. 9, SW. qr.) the following section is shown at the Good coal mine.

		Feet.
18.	Limestone, yellow, impure	3
17.	Shale, sandy	6
16.	Shale, black, laminated, with iron-stained concretions	2
15.	Shale, light and dark	8
14.	Coal	1½
13.	Fireclay	2½
12.	Shale, sandy	7
11.	Sandstone, fine-grained	2½
10.	Shale and sandstone	20
9.	Shale, black	1½
8.	Sandstone	2
7.	Shale, black	4
6.	Coal	1½
5.	Shale, sandy, light-colored	9
4.	Limerock, hydraulic	1
3.	Shale, black	1½
2.	Coal	3½
1.	Clay, potters'	2 to 3

The potters' clay mentioned at the base of the above section is probably the same seam as that worked at Calhoun and Clinton, and is an excellent quality for stoneware.

CLINTON.

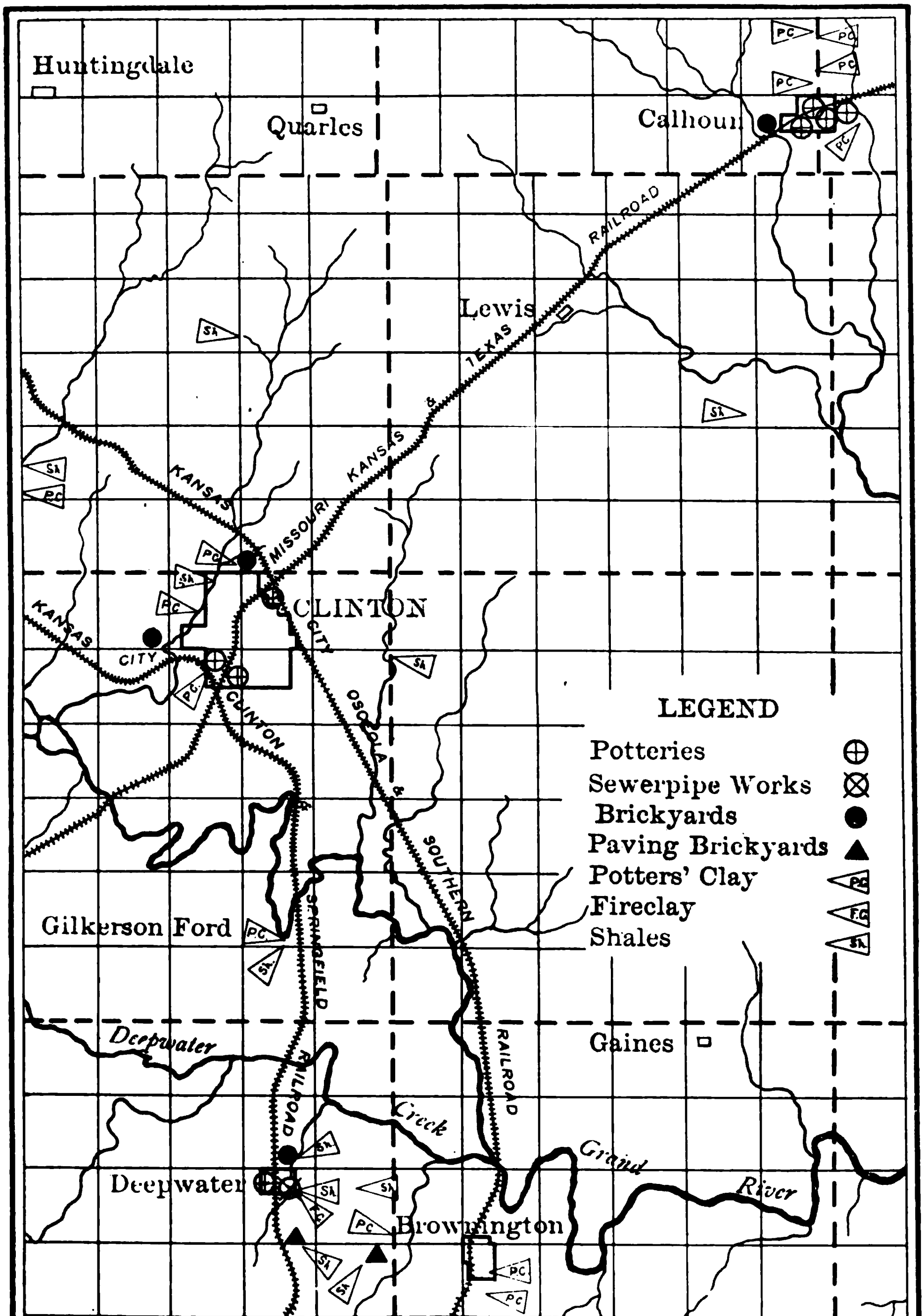
In the cut of the Kansas City, Ft. Scott and Memphis railroad about half a mile south of the town, the following section is exposed:

		Feet.
5.	Soil	1
4.	Sandstone	2
3.	Shale, yellow, highly lamellar, soft and plastic, with thin limonite layers at base	1
2.	Clay, potters', blue to gray	4 to 5
1.	Shale, sandy, brown, very ferruginous (base of cut)	2

The potters' clay is somewhat iron-stained, rather fat, but seems to be of excellent quality for stoneware. It was used at the Gulf pottery in Clinton and found very favorable for pottery purposes.

Frowein Pit. About one mile west of Clinton is the Frowein shale pit which was opened in 1890. It furnishes most of the potters' clay used in the Clinton potteries, and ships to some extent to outside markets: The following section is exposed:

		Feet.
5.	Shale, sandy, light gray	4
4.	Shale, sandy, gray	1
3.	Shale, yellow, sandy	1
2.	Sandstone, soft, gray, ferruginous	1
1.	Shale, sandy, dark gray, somewhat iron-stained	5



MAP OF THE CLAY DEPOSITS OF HENRY COUNTY.

The bed of the shale at the base of the section is the one used in the local potteries. A sample gave the following characteristics: Color variable, very light gray to olive green to blue to black, very much stained yellow to brown by iron. Texture laminated, fine-grained, rather soft, and not uniform. Taste, gritty and fat. Slacked slowly but completely into coarse granules. Pyrite was not visible, but a few very small mica flakes were present. When ground to 20-mesh and mixed with 21.5 per cent of water it made a plastic paste that shrunk 7.7 per cent on drying and 4.0 per cent when vitrified, giving a total shrinkage of 11.7 per cent. Briquettes of the air-dried mud gave an average tensile strength of 143, and a maximum of 164 pounds to the square inch. Incipient vitrification occurred at 1,950° F., complete at 2,150°, and viscous above 2,350°. It rapidly dried and heated without cracking, and burned to a brown compact, tough body, when vitrified.

An anyalysis gave the following results:

	Per cent.
Silica	64.97
Alumina	22.64
Water	5 50
Sesquioxide of iron	3.28
Lime	0.61
Magnesia	0.80
Alkalies	2.74
Total	100.54
Total fluxing impurities	7.43
Specific gravity	2.37

Fields Creek. About four miles northwest of Clinton (Tp. 42 N., R. XXVI W., Sec. 29, NW. qr.), on Fields creek, Ladd found the following section:

		Feet.
13.	Limerock, hydraulic	1¼
12.	Fireclay, calcareous	2½
11.	Shale, black, with concretions	1
10.	Shale, black, with fossils	6
9.	Coal	3
8.	Fireclay, impure (1 foot ferruginous)	3¼
7.	Coal	1
6.	Fireclay	1
5.	Shale, black, soft, contains alum (taste)	5
4.	Coal	½
3.	Fireclay, impure, sandy	3
2.	Sandstone	⅛
1.	Clay, potters' (sample tested)	4

A sample of the potters' clay that was collected had the following characteristics: Color light gray, to bluish black with yellow to brown iron stains. Texture soft, laminated, very fine-grained and uniform. Taste, rather fat and decidedly of alum. Slacked very slowly and imperfectly into coarse granules. Pyrite was present as small seams and crystals. When ground to 20-mesh and mixed with 18.5 per cent of

water it made a decidedly plastic paste that shrunk 6.5 per cent in drying and 4.0 per cent when vitrified, giving a total shrinkage of 10.5 per cent. Briquettes of the air-dried mud gave an average tensile strength of 140, and a maximum of 163 pounds to the square inch. Incipient vitrification occurred at 1,800° F., complete at 2,000°, and viscous above 2,200°. It dried rapidly and heated without checking, and burned to a red to brown, compact, tough, body when vitrified.

An analysis gave the following results:

	Per cent.
Silica	55.39
Alumina	25.79
Water	8.60
Sesquioxide of iron	4.83
Lime	0.53
Magnesia	0.81
Alkalies	3.39
Total	99.34
Total fluxing impurities	9.56
Specific gravity	2.33

Grant Farm. On the Grant farm three and one-half miles north of Clinton the following section is to be seen on the bank of the creek:

		Feet.
6.	Soil	2
5.	Shale, sandy, yellow, and gray (sampled)	6
4.	Shale, soft, fat, black to drab	5
3.	Sandstone, coarse, yellow	1
2.	Shale, black	2
1.	Coal (exposed)	2

A sample of the top shale that was collected gave the following characteristics: Color olive green to yellow, with occasional brown iron stains. Texture fine, laminated, very fine-grained, soft and uniform. Taste, fat. Slacked slowly and perfectly into fine granules. Pyrite was not noticeable. When ground to 20-mesh and mixed with 21.5 per cent of water it made a very plastic paste that shrunk 8.0 per cent in drying and 4.0 per cent when vitrified, giving a total shrinkage of 12.0 per cent. Briquettes of the air-dried mud showed a tensile strength of 189, and a maximum of 207 pounds to the square inch. Incipient vitrification occurred at 1,900° F., complete at 2,100°, and viscous above 2,300°. It dried rapidly, but required slow heating and cooling to avoid checking. It burned to a pink to gray, tough, compact mass when vitrified. This bank has not been utilized as yet but it is well adapted for stoneware.

An analysis gave the following results:

	Per cent.
Silica	57.33
Alumina	25.09
Water	8.74
Sesquioxide of iron	4.09
Lime	0.84
Magnesia	1.17
Alkalies	2.74
Total	100 00
Total detrimental impurities	8.84
Specific gravity	2.26

Gilkerson Ford Clay. A sample that was collected by Ladd of the seam of fireclay that outcrops on the bank of the Grand river, at the Gilkerson ford, five miles south of Clinton and the details of which section are mentioned in the chapter on "Shales" had the following characteristics: Color light gray and occasionally stained yellow to brown with iron. Texture massive, compact, fine-grained, sandy, and uniform. Taste, very lean and gritty. Slacked very slowly and imperfectly. Pyrite was not visible, but white scales of mica were sparingly distributed. When ground to 20-mesh and mixed with 18.0 per cent of water it made a decidedly short to very slightly plastic mass that shrunk 5.3 per cent in drying and 6.0 per cent when vitrified, giving a total shrinkage of 11.3 per cent. Briquettes of the air-dried mud gave an average tensile strength of 54, and a maximum of 60 pounds to the square inch. Incipient vitrification occurred at 2,100° F., complete at 2,300°, and viscous above 2,500°. It dried rapidly, and heated without cracking. It burned to a buff to gray, strong dense body when vitrified.

An analysis gave:

	Per cent.
Silica	76.99
Alumina	14 72
Water	3.86
Sesquioxide of iron	2.48
Lime	0.65
Magnesia	0.58
Alkalies	2.38
Total	101.66
Total fluxing impurities	6.09
Specific gravity	2.36

This clay is almost refractory enough to meet the demands of fire-brick. It is well adapted for stoneware, though it is not yet utilized for that purpose.

BROWNINGTON.

One mile west of the town is the Blair clay pit, from which about 32 cars or 620 tons a month are shipped to the Kansas City Sewer Pipe Co. for sewerpipe. The top shale and the two seams of potters' clay are worked, which is sold for $4.00 a car of 20 tons, of which $1.00 or five cents a ton is royalty. The following section is exposed at this place:

		Feet.
7.	Soil	1
6.	Sandstone, gravel, yellow clay	½
5	Sandstone	½
4.	Shale, sandy	5
3.	Clay, potters'	5
2.	Coal	1
1.	Clay, potters'	4

A sample of the lower potters' seam taken gave the following characteristics: Color light gray, reddish brown, or bluish black with copious yellow brown iron stains. Texture coarsely lamellar, very fine-grained, soft, uniform. Taste, gritty in some layers, though mostly fat and a little of alum. Slacked slowly into coarse granules. Pyrite not noticeable; white mica present in small amounts. When ground to 20-mesh and mixed with 19.0 per cent of water it made a plastic paste that shrunk 6.0 per cent in drying and 6.0 per cent when vitrified, making a total shrinkage of 12.0 per cent. Briquettes of the air-dried mud showed an average tensile strength of 110, and a maximum of 127 pounds to the square inch. Incipient vitrification occurred at 2,000° F., complete at 2,200°, and viscous above 2,400°. It required to be rather slowly dried and slowly heated to avoid cracking. It burned to a brown to gray tough dense body when vitrified.

An analysis gave the following results:

	Per cent.
Silica	67.49
Alumina	21.11
Water	5.95
Sesquioxide of iron	2.45
Lime	0.17
Magnesia	0.63
Alkalies	2.83
Total	100.63
Total fluxing impurities	6.08
Specific gravity	2.23

MONTROSE.

Ladd gives the following section at Montrose, on Price creek, (Tp. 40 N., R. XXVIII W., Sec. 26, NW. qr.):

		Feet.
6.	Soil and clay	6
5.	Shale, dark	6
4.	Coal (impure)	½
3.	Clay, potters', outcrop under creek	2½
2.	Shale, sandy, greenish	3
1.	Coal (exposed)	1

DEER CREEK.

The following section in the level country near Deer creek (Tp. 44 N., R. XXV W., Sec. 7, NW. qr.) is given by Ladd:

		Feet.
11.	Soil	1
10.	Sandstone	2
9.	Shale, sandy, light colored	4
8.	Shale, black	4
7.	Shale, dark, iron-stained	5½
6.	Coal	1
5.	Fireclay	4½
4.	Coal	4
3.	Fireclay, hard, sandy, considerably iron-stained	6
2.	Shale, black	2
1.	Coal	3½

The two thick seams of so-called fireclay are probably very satisfactory for stoneware.

HICKORY COUNTY.

Hickory county is underlain by the limestones and sandstones of the Silurian, except in the extreme northwestern corner, where the purer limestones of the lower Carboniferous occur, which are liable to contain pockets of high grade clay.

On the Loomis land, at the south end of Quincy (Tp. 38 N., R. XXIII W., Sec. 31, SW. qr.) four feet of white clay was encountered in sinking a well. The indications are that it is a good grade of potters' clay. A white clay is also said to have been struck in another well about 600 feet southeast of the above. It was impossible to obtain samples.

About three miles north of Humansville, on the Crithfield land (Tp. 31 N., R. XXIV W., Sec. 2, NW. qr.) 16 feet of potters' clay were passed through at a depth of 8 feet in sinking a well. Specimens of clay that are said to have come from here are fine-grained, fat, soft, and mixed red to pink or gray in color. It appears to be more of an impure kaolin, but is evidently well-adapted to the manufacture of stoneware.

HOWARD COUNTY.

The coal measures cover most of the county, excepting in the southern and western portions, where the limestones of the lower Carboniferous make their appearance. There is a workable seam of fireclay under one or more of the coal beds in this county that probably make a fair grade of stoneware, and some of it is sufficiently refractory to answer for firebrick. The location is very favorable for the occurrence of the other fireclay seams that usually occur at the base of coal measures.

JASPER COUNTY.

Jasper county is mainly underlain by the limestones of the lower Carboniferous, except in the northwestern corner, where there is a remnant of the lower coal measures. In the lead and zinc mines around Joplin in which are the ore-bearing chert and limestones, shales and clays are frequently encountered that belong to the lower coal measure formation. The shales are usually too impure and too limited and local to be desirable stoneware clays, but occasionally the clays which are misnamed fireclays may answer for stoneware purposes. The overlying pockets or remnants of the coal measures are local and of limited size, yet they may be large enough to furnish several thousand tons of clay.

Carthage. In the railroad cut on the spur connecting the Missouri Pacific and the St. Louis and San Francisco railroads an exposure of coal measures gives the following section:

		Feet.
6.	Chert, gravel, and red clay	4
5.	Shale, soft and fat	6
4.	Shale, black	2
3.	Coal	½
2.	Fireclay, very ferruginous	4
1.	Shale, soft	2

In the absence of tests, no statement can be made as to the value of this fireclay. It seems probable that if it was formerly used at the Carthage stoneware pottery, it could not have been very successful, as the pottery now imports its clay from Calhoun.

Joplin. At the Chaney shaft, on the Gregg land, four miles southwest of the town, the following section was observed in sinking the shaft:

		Feet.
7.	Gravel	3
6.	Clay, potters', gray (sample 103)	12
5.	Clay, gray to red	10
4.	Clay, black, mottled	11
3.	Sandstone	7
2.	Chert, red horizon in chert	12
1.	Chert and limestone (ore horizon)	16

A sample of the gray clay gave the following characteristics: Color mostly light gray, partly black, with occasional pink to yellow iron stains. Texture massive, compact, hard (2.0 to 2.5), and rather fine-grained. Taste, lean. Slacked quickly to one-twentieth to one-sixth of an inch granules, and the black more slowly to one-eighth to one-half inch granules. Pyrite was not noticeable. When ground to 20-mesh and mixed with 16.0 per cent of water it made a very plastic paste that shrunk 7.0 per cent in drying and 6.0 per cent when vitrified, giving a total shrinkage of 13.0 per cent. Briquettes of the air-dried mud gave an average tensile strength of 210, and a maximum of 239 pounds to the square inch. Incipient vitrification occurred at 1,650° F., complete at 1,850°, and viscous above 2,100°. It was necessary to slowly dry and heat the clay to avoid checking. It burned to a compact, strong, gray body when vitrified, that is slightly mottled with black specks, which washing removes. It would make an excellent stoneware clay.

An analysis gave the following results:

	Per cent.
Silica	60.98
Alumina	21.83
Water	8 48
Sesquioxide of iron	1.93
Lime	0.42
Magnesia	1.95
Alkalies	4.69
Total	100 28
Total fluxing impurities	8.99
Specific gravity	2.29

This clay is not utilized and in fact its presence is greatly regretted by the miners, as it causes some trouble in timbering and holding the ground. It is highly suggestive of purer bodies of clay occurring in the mineral district.

On lot 36, of the King Soloman mine it is said that the shaft went through 20 feet of fireclay, under 8 to 10 feet of surface gravel. As the shaft was tightly timbered when visited this statement could not be verified, but as the information was derived from a trustworthy source it is worthy of investigation. Two hundred feet west of the preceding one, on the Greggs land, fireclay shows on the dump of one of the shafts; while apparently there is not a large body of it the quality seems to be excellent. At the Bodine shaft one-half mile southwest of Joplin, 25 to 30 feet of potters' clay were passed through in sinking the shaft. It is mainly gray, though heavily stained yellow and brown by iron. It is soft, plastic, and when washed it may prove a satisfactory stoneware clay. A shaft about 300 feet north of the preceding also

shows more or less gray shale and some clay. At the Columbia shaft, on the Hemingway land, two miles southeast of Joplin, 10 feet of potters' clay were found under black shales at a depth of 60 feet. The clay is light gray, uniform in color, and rather coarse-grained. It slacks completely and readily, and is a typical coal measure variety. It contains a large amount of pyrite as coarse crystals that are very freely disseminated, but they could be easily removed by washing.

Webb City. On the Woodward land, one mile north of the town near the ice factory, it is stated that there are 26 feet of white clay that covers one and one-half acres. It has been shipped to east Liverpool, Ohio, to the white-ware potteries, while the less pure clay was used for fire-brick.

JOHNSON COUNTY.

Johnson county is underlain by the coal measures, and contains, especially in the eastern portions, workable seams of potters' clay and probably shales that are suitable for stoneware. It lies immediately north of Henry county, which is famous for its excellent stoneware clay that is obtained at the base of the coal measures. Montserrat and Knob Noster have already become producing centers, and there are other places equally as desirable if they possessed favorable shipping facilities.

The Boyd bank is one-half mile west of the Knob Noster station on the Missouri Pacific railroad, with which it is connected by a private switch. The following is a section of the bank as worked:

	Feet.
8. Soil and gravel	1
7. Clay	2
6. Clay, potters' (seam A.)	3½
5. Coal	1-6
4. Clay, potters', sandy (seam B)	2
3. Clay, with nodules of iron	1
2. Shale, blue	3
1. Shale, highly ferruginous, sandy (exposed)	1

The seam A is a tough, plastic, bluish gray clay that is very freely streaked yellow to brown by iron. It is hard, compact, rock-like at the base, but has disintegrated into soft, plastic clay at the top. One hundred feet to the west, the seam is overlain by six inches of very ferruginous sandstone that is almost a lean iron ore, over which are two feet of greenish gray shale, one inch of coal and two feet of blue shale. The seam B is gray to bluish, hard and rock-like when freshly mined and very sandy. A sample collected gave the following characteristics: Color light to dark gray and somewhat stained yellow to brown by iron. Taste lean and gritty. Texture compact, slightly laminated, hard (2.0 to 2.5), rather coarse-grained, sandy and uniform.

Slacked slowly but completely to coarse granules one sixteenth to one-half of an inch in size. Pyrite was not noticeable. When ground to 20-mesh and mixed with 19.0 per cent of water it made a plastic mass that shrunk 6.0 per cent in drying and 5.0 per cent when vitrified, giving a total shrinkage of 11.0 per cent. Briquettes of the air-dried mud gave an average tensile strength of 120, and a maximum of 129 pounds to the square inch. Incipient vitrification occured at 2,000° F., complete at 2,150° and viscous above 2,300.° It dried rapidly, heated without checking and burned to a tough, strong cream to light gray body with slight brown spots of iron.

An analysis gave the following results:

	Per cent.
Silica	69.96
Alumina	20.41
Moisture	5.84
Sesquioxide of iron	2.11
Lime	1.21
Magnesia	trace
Alkalies	1.52
Total	100.24

The entire bank is worked, except the surface gravel and the seam of nodular iron concretions, and is loaded on board the cars and shipped to the Kansas City Sewer Pipe Co. to be made into sewer-pipe. The mixture of clay and shale is put on board cars at Knob Noster for 35 cents a ton, while the freight (75 miles) amounts to 60 cents a ton additional. The bank was opened in 1887, and shipped about 300 cars or 6,000 tons a year for three years; this has since been increased to 350 cars, or 7000 tons for the past two years. The seam "B," is sorted out by itself, and shipped to the Argentine smelter, near Kansas City, to the extent of two cars a month. The principal competitor of Knob Noster for the Kansas City sewer-pipe trade is Deepwater, in Henry county.

At the Gall coal shaft No. 1, one and one-half miles southwest of Knob Noster the following is an average section of several bore holes:

		Feet.
13.	Surface clay	10
12.	Shale, gray	4
11.	Coal	1½
10.	Clay, potters' (seam A)	4
9.	Sandstone, blue	13
8.	Shale, blue	4
7.	Coal	½
6.	Shale, gray	8
5.	Limerock, blue	1
4.	Shale, black	17
3.	Coal	4
2.	Clay, potters' (seam B)	11
1	Shale, black (exposed)	1

The seam B of potters' clay that underlies the bottom coal was tried at the Montserrat works, but it was found to be too fusible for refractory purposes, but answers fairly well for stoneware.

KNOX COUNTY.

The glacial drift obscures the underlying formations, except where erosion has removed it in the valleys and ravines. The underlying formation is very favorable for the occurrence of potters' clay in the northwestern portion of the county, where the coal measures are rich in clay and shales, some of which are suitable for stoneware. The rest of the county is underlain by lower Carboniferous limestones, with occasional shales, but these are not likely to be productive of extensive beds of clays suitable for stoneware purposes.

The neighborhood of Edina is said to have been prospected 17 years ago for the Edina brickyard. It is stated that abundance of potters' clay was found, but that it cracked on drying so that there are no potteries there at present.

LAFAYETTE COUNTY.

Lafayette county is underlain by the coal measures. A seam of two to four feet of so-called fireclay quite persistently underlies the Lexington coal seam, where it is sufficiently thick to be workable, but unless it is of much better quality than at Mayview it is too fusible from the excess of lime and other impurities. This seam as well as other so-called fireclays and shales are worthy of further investigation.

Lexington. In a ravine at the foot of Park street, 200 feet from the Missouri river, is exposed the following section:

		Feet.
11.	Loess and yellow clay	20
10.	Limestone, gray, thin bedded	2½
9.	Shale	1½
8.	Limestone	¼
7.	Shale	16
6.	Limestone	½
5.	Shale, black	2
4	Limestone, blue	5
3.	Shale, black	2½
2.	Coal	2
1.	Fireclay	5

The so-called fireclay seam that occurs under the coal is heavily iron-stained and contains much carbonate of lime. This clay, like that at Mayview, is too fusible for stoneware and it is extremely liable to blister.

Napton. There is a seam of so-called fireclay underlying the coal at Napton that is said to be about 10 feet thick. From its general simi-

larity of character to the other so-called fireclays in this county it strongly indicates that it cannot be used.

Mayview. The fireclay seam under the coal vein that is being worked at the Strasburg mine, one mile east of Mayview on the Chicago, Alton and St. Louis railroad, ranges from two to four feet in thickness. The tests and analysis show that it is too impure for good stoneware. It gave the following characteristics: Color, light gray, slightly stained brown with iron. Texture massive, compact, hard (2.0 to 2.5), and fine- to coarse-grained, with small concretions of carbonate of lime. Taste, rather fat. Slacked readily into one-eightieth to one-tenth of an inch granules. Pyrite was not noticeable; hydrochloric acid caused copious effervescence. When ground to 20-mesh and mixed with 22.0 per cent of water it made a very plastic paste that shrunk 8.8 per cent in drying and 0.8 per cent when vitrified, giving a total shrinkage of 9.6 per cent. Briquettes of the air-dried mud gave an average tensile strength of 270, and a maximum of 284 pounds to the square inch. Incipient vitrification occurred at 1,700° F., complete at 1,850°, viscous above 1,900°. It required very great care in drying to prevent checking or cracking, but rapidly heated. It formed a gray to brown, compact, rather strong vitrified body when slowly burned.

An analysis gave the following results:

	Per cent.
Silica	48.12
Alumina	17 04
Water and carbonic acid	14.98
Sesquioxide of iron	3.82
Lime	9.90
Magnesia	2.65
Alkalies	2.97
Total	99.74
Total fluxing impurities	19.34
Specific gravity	2 34

LAWRENCE COUNTY.

The county is underlain by the limestones and occasional shales of the lower Carboniferous period. They are seldom continuous beds of either clay or shale that are suitable for stoneware, but there are liable to be deposits of value for vitrified brick. Some small prospects are known that are somewhat encouraging, but no large deposit or bank has been thus far opened.

Three-fourths of a mile east of Pierce City, on the Fagan farm, occurs a coarse, white, tallow clay that was formerly used with Calhoun clay in making stoneware. By mixing this with one-half Calhoun clay it made a very good quality of goods.

The seam B of potters' clay that underlies the bottom coal was tried at the Montserrat works, but it was found to be too fusible for refractory purposes, but answers fairly well for stoneware.

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MARION COUNTY.

About one mile south of Hannibal and half a mile west of the Mississippi river, a potters' clay occurs just below the crest of the high hills which form the bluffs of the river, that was formerly used in a local stoneware pottery. It seems to be a pocket of clay in the limestone, as the latter outcrops on all sides at a higher level. It is a fat, fine-grained, slightly greenish colored clay that is more or less yellow stained by iron; it also has streaks of white carbonate of lime. Swallow notes the occurrence of "pipe clay," by which he probably means a stoneware clay, on the Meleck and the White lands on the south side of New river; also on the Barnes land, east of Cedar creek; also on the Hays and Mulderow farm (T. 57 N., R. VII W. Sec. 20), and in section 10, south of Sharp park where it is obtained for the pottery of Olden and Davis.

Slip-clay is found on Bear creek near the old Badger lumber plant, and while the clay is excellent it is said to be too infusible to give the best results. Slip clay is also said to occur at New Market, on the Hannibal and St. Joseph railroad, but the quality is not very good.

MONITEAU COUNTY.

Limestones of the lower Carboniferous and Silurian occupy most of the district. These are therefore not likely to contain continuous beds of clay or shale that are suitable for stoneware pottery; but local pockets occur that may justify extensive work, as occasionally these deposits are quite large. Swallow mentions the occurrence of numerous pockets of potters' clay but only mentions the location of one. Two miles northeast of Tipton, on a small branch running east, a grayish-green, tough, plastic, fine-grained clay crops out on the banks of a branch; there are over three feet in sight, which is slightly iron stained and is capped by three to four feet of soil and gravel. One-half mile north of the above outcrop apparently the same bed of clay is exposed on the bank of a small branch at the crossing of the county road. The same clay is again seen about four miles northeast of Tipton, in the bed of a brook, under a capping of two feet of gravel, but it is more greenish at this place. It is also exposed about five miles east of Tipton, in a small branch. About five miles south of California, on the Blackburn land (Tp. 43 N., R. XV W., Sec. 24) a light blue pipe-clay is said to occur that is suitable for the manufacture of stoneware.

MONROE COUNTY.

Remnants or outliers of the coal measures cover the hills of the district, while the valleys are eroded down to the lower Carboniferous limestones. Fireclays of superior quality occur at or near the base of the coal measures, and when these are not too pure they make excellent stoneware. The shales are also sometimes used by the local potteries so that there is an abundance of material in the county for stoneware purposes.

Paris. In the neighborhood of Paris there is considerable potters' clay. A pottery formerly located four miles north of the town depended on a local bank of clay. On the West place, one mile east of Paris, is a deposit of potters' clay, but it is said to make a brittle ware. Other deposits occur on the Moxie place north of Paris and also one mile west.

Stoutsville. About two and one-half miles west, on the Paris road is the site of an abandoned stoneware pottery. It is at the clay bank that supplies the present Stoutsville pottery. There is exposed a face of four feet of light, massive, very plastic, fine-grained clay under six feet of glacial drift. The thickness of the deposit varies from 2 to 25 feet. The clay is slightly stained yellow by iron, and it occasionally contains pebbles. There is a sharp line of demarkation between it and the overlying brown glacial drift. The bank is almost on the crest of a gentle hill, and 100 feet above the branch of the Salt river. The clay is washed in a crude washing outfit consisting of a tub or box 15 feet in diameter, through which is dragged two harrows by a horse, which works the clay into a thin paste; the slip or thin clay gruel is then sifted through a 60-mesh screen and settles in vats that are 50 feet long by 25 feet wide. The washed clay is utilized at the new pottery at Stoutsville and makes an excellent quality of ware, while it can be exposed directly to the sun after moulding without cracking.

Two miles west of Stoutsville, in a cut on the Missouri, Kansas and Texas railroad 8 feet of clay are exposed. About one mile west of the Conrad place, on the Tanner farm, potters' clay shows in the roadside under sandstone. One mile southwest of the town a white to yellow, soft, plastic, fine-grained clay crops out at the roadside, under three feet of soil and it rests on flint bowlders. It shows for 100 feet and seems to be a remnant or pocket on the flank of a gentle hillside; its apparent thickness is over one foot, but further development may prove it to be much more extensive. Northwest of the town one and one-half miles and one-fourth mile north of the Conrad clay pit (Tp. 55 N., R. IX W., Sec. 15, NE. qr.) is the Sponsler pit. The potters'

clay is light gray and also crops out in a ravine. Over five feet are exposed. Very white clay also outcrops near the bank of Salt river nearby; and also on the Ellis place. About one-half mile southeast of Stoutsville, on the Woodson place, a white clay was encountered in digging a well 10 feet deep. About 500 feet to the east a light gray, soft plastic clay is exposed in the bank of a small branch, but only one foot is in sight. Three miles east of Stoutsville, on the Painter farm, potters' clay occurs on a small branch.

Clapper. Three miles west of Clapper, at the Danenhouer and Winder pottery (Tp. 56 N., R. IX W., Sec. 24, SW. qr.) is a bank of potters' clay that has been previously described under fireclays. In the impurities and coarseness of the grain it is so exceptionally high as to make it one of the most refractory clays in the state if not in the world. It is moderately plastic, and is utilized by glazing it with salt, which on account of its highly silicious character, is effected without much difficulty. Though it is used for stoneware purposes, its very refractoriness makes it more valuable for fire-brick.

Clinton. One mile southwest of Clinton (Tp. 56 N., R. IX W., Sec. 32, SW. qr.) on the Randall place were found from seven to eight feet of potters' clay, under two feet of soil, in excavating for a stock pond. The clay was tested at the Tanner pottery and found to make excellent ware. On the adjoining Geary farm potters' clay shows under two feet of soil, for 100 feet, and is over two feet in thickness. It is a fine-grained, very plastic clay, with occasional iron stains. About one-fourth mile south of the above on the Ansole place, at the point where a small branch crosses the road, a gray, plastic clay outcrops. It is considerably stained red and yellow with iron but otherwise appears to be the characteristic potters' clay of this district.

Goss. Near this place (Tp. 55 N., R. IX W., Sec. 29, NW. qr.) there occurs a soft gray to drab fireclay that is massive, quite hard, lean to fat and appears to be a clay of excellent quality. It is probably highly refractory. There are eight feet in sight on the bank of the creek.

MORGAN COUNTY.

The general character of the geology of Morgan county is considered in the chapter on "Fireclays."

Price Clay Pit. One-half mile northeast of Versailles, on the Price land, 40 feet of tough plastic clay were passed through in sinking a shaft in search of mineral. A sample of this clay gave the following characteristics: Color light greenish gray, slightly stained yellow to brown by iron. Texture massive, soft, fine-grained and uniform. Taste, somewhat fat to slightly sandy. Slacked rather readily and

completely to one-eightieth to one-fiftieth of an inch granules and a gray variety less perfectly to one-thirtieth of an inch granules. Pyrite was not noticeable. When ground to 20-mesh and mixed with 20.0 per cent of water it made a plastic paste that shrunk 10.4 per cent in drying and 5.4 per cent when vitrified, giving a total shrinkage of 15.8 per cent. Briquettes of the air-dried mud gave an average tensile strength of 150, and a maximum of 175 pounds to the square inch. Incipient vitrification occurred at 1,600° F., complete at 1,750°, and viscous above 1,900°. It required to be very slowly dried to avoid checking, but heated rapidly. It burned to a red-brown, compact, tough body when vitrified.

An analysis gave the following results:

	Per cent.
Silica	54.10
Alumina	24.00
Water	11 64
Sesquioxide of iron	4 01
Lime	1.31
Magnesia	1.25
Alkalies	4.01
Total	100 32
Total fluxing impurities	10.58
Specific gravity	2.25

Its low fusibility and color make it undesirable for the best grades of stoneware, but it is well adapted for earthenware, sewerpipe, vitrified brick and other coarse products.

NODAWAY COUNTY.

At the Harris coal shaft near Quitman (Tp. 64 N., R. XXXVII W., Sec. 9) a seam seven feet thick of fireclay occurs under the coal at a depth of 50 feet. The clay is dark gray, hard, massive and sandy. It appeared to be a fair grade of potters' clay. It may be possibly refractory but there was no opportunity to test the clay in this respect. At the Roberts coal shaft there are eight feet of good clay and at the Pierson drift, about one-half mile southeast of Quitman, two feet of fireclay occur under a seam of coal. There are two and one-half feet of clay under a coal seam at a depth of 15 or 20 feet, on the Sargent, farm, which is four miles southwest of Hopkins. The clay is quite fusible but it may answer for stoneware purposes. On the Otis land there are 10 feet of fireclay, but it is said that a test showed it was unsatisfactory for refractory purposes and stoneware.

OZARK COUNTY.

The three small stoneware potteries at Gainesville obtain clay in the immediate vicinity. As the potteries are small, and only work for a limited local trade, little clay is taken out. The clay seems to be

residual and is well adapted for the manufacture of stoneware. About two miles northeast of the town, on the Forbes land (Tp. 23 N., R. XIII W., Sec. 31, NE. qr.), a sandy white to gray potters' clay is disclosed in the bed of a creek for 100 feet in length. It is somewhat yellow stained, from the sand, but when used at the Dunnegan pottery, about 10 years ago, it was claimed that the sand faded out. The seam shows further up the ravine where there is a face of clay 13 feet high that is uniform, and gray to slightly yellow stained. On the edge of the same quarter section about one-fourth mile west of the Forbes house a coarse, gray, plastic clay is exposed in the bottom of a small branch. Several other exposures of gray, plastic clay occur in the vicinity of the branch, but none of them have been developed sufficiently to show their magnitude or quality.

PETTIS COUNTY.

There is an excellent potters' clay three miles north of Dresden, on the Missouri Pacific railroad. The clay is overlain by three feet of soil and stripping. It is said to be a very safe, drying clay, standing rapid drying without checking. It was formerly used at the Stein pottery, at Dresden, for making stoneware.

POLK COUNTY.

A bed of secondary clay occurs near Bolivar that was derived from the ferruginous sandstone and shales. The clay has been used at a small local pottery to a small extent. Three miles from Bolivar, on the Moore farm, are three to six feet of potters' clay.

PUTNAM COUNTY.

Putnam county is underlain by coal measures and contains beds of shale and so called fireclay that are suitable for stoneware purposes. Under the coal near Unionville the clay is more than thick enough to be profitable should the quality prove satisfactory. This would become an important occurrence from its proximity to a good market and cheap coal. The Mystic coal seam is widely spread under the northern part of the county, and underlying it is a fireclay two to three feet thick. On the Chariton river the seam is above the water-level, but at Mendota, at the Blackbird coal shaft, on Blackbird creek, it is 53 feet from the surface, and farther west still deeper. Six miles southeast of Unionville there are seven feet of clay under the coal seam at the Bigg shaft.

RANDOLPH COUNTY.

In Randolph county there are at least two seams of fireclay and at least two beds of shale that are suitable for the manufacture of stoneware. These seams are found throughout nearly the entire county, though they vary both in thickness and quality. They have been utilized as yet to only a moderate extent, but if the trouble were taken to wash them a very fair grade of potters' clay can probably be obtained from them.

Moberly. About one mile north of the Union railroad station is the Lanigan shaft, which is sunk to a depth of 240 feet to reach a thin coal seam that was formerly extensively worked. Associated with the coal is a thick fireclay seam. The following is the section :

	Feet.
6. Clay, glacial	85
5. Sandstone	115
4. Coal	½
3. Clay, potters'	10
2. Shale, black	30
1. Coal	3

This clay was tested by the Mexico Fire Brick Co., with the intention of erecting a plant. A sample collected gave the following characteristics : Color gray to drab. Texture massive, compact, hard (2.0 to 2.7), and coarse-grained. Taste, lean and sandy. Slacked readily and completely to one-fortieth to one-eight of an inch granules. Pyrite was present as occasional small crystals, while fossil leaves were quite abundant. When ground to 20-mesh and mixed with 16.0 per cent of water it made a plastic paste that shrunk 5 5 per cent in drying and 4.5 per cent when vitrified, giving a total shrinkage of 10.0 per cent. Briquettes of air-dried mud gave an average tensile strength of 120, and a maximum of 125 pounds to the square inch. Incipient vitrification occurred at 2,000° F., complete at 2,200°, and viscous above 2,400°. It dried rapidly and heated without checking and burned to a gray body, with mottlings due to disseminated iron.

An analysis gave the following results:

	Per cent.
Silica	66.26
Alumina	20.32
Water	7 80
Sesquioxide of iron	2.30
Lime	0 63
Magnesia	0.48
Alkalies	2 04
Total	99 83
Total fluxing impurities	5.45
Specific gravity	2.52

Huntsville. On the Newman place (Tp. 54 N., R. XV W., Sec. 11, SW. qr.) are four feet of potters' clay under a thick coal seam. Samples of it were made up into jugs and pots, but they showed pittings and markings due to the iron. The clay should be washed before being used to remove the objectionable impurities. About three and one-half miles northwest of Huntsville on the Hammett farm (Tp. 54 N., R. XV W., Sec. 14, SW. qr.) are four feet of potters' clay that crops out on the bank of a small creek. It is overlain by a thin seam of coal above which are six feet of shale and two of soil. The clay is very favorable for mining as it is above water level and the stripping is moderate; it could also be worked by drifting. A sample of this clay gave the following characteristics: Color variable, from light gray to grayish black, with occasional yellow iron stainings. Texture massive, compact, hard (1.5 to 2.0), coarse-grained and uniform. Taste, lean and sandy. Slacked readily to one-fortieth to one-tenth of an inch granules. Pyrite was not noticeable. When ground to 20-mesh and mixed with 17.0 per cent of water it made a plastic paste that shrunk 7.0 per cent when dried and 4.0 per cent when vitrified, giving a total shrinkage of 11.0 per cent. Briquettes of the air-dried mud gave an average tensile strength of 118, and a maximum of 125 pounds to the square inch. Incipient vitrification occurred at 2,000° F., complete at 2,200°, and viscous above 2,400°. It dried rapidly, but required slow heating to avoid cracking. It burned to a very tough, gray to brown ware when vitrified.

An analysis gave the following results:

	Per cent.
Silica	66.08
Alumina	21.74
Combined water	6.00
Moisture	1.34
Sesquioxide of iron	2.13
Lime	0.50
Magnesia	1.01
Alkalies	1.64
Total	100.39
Total fluxing impurities	5.28
Specific gravity	2.53

This clay seam also outcrops about 1,500 feet east of the point at which the sample was taken. One mile south of the town two and one-half feet of soft, plastic, fine-grained potters' clay are exposed at the roadside under a coal seam. It is considerably stained yellow by iron, but otherwise seems to be favorable for working into stoneware. In the southeast quarter of section 28 (Tp. 53 N., R. XV W.) on the bank of Silver creek, the Huntsville clay seam is exposed; it is a hard,

compact, gray clay, with some cross seams of pyrite and calcite, but the latter are easily removed by washing.

Thomas Hill. Under the coal seam at Thomas Hill (for detailed section see chapter on "Shales") there are five feet of clay that may answer for stoneware. It is gray, fine-grained, plastic, considerably stained yellow by iron, and contains a streak of calcite crystals immediately under the coal. Washing would eliminate these and make a fair grade of stoneware.

Darksville. Three miles west of this place (Tp. 55 N., R. XV W., Sec. 19) near Sheridan creek, 4 to 5 feet of clay outcrop under a thick coal seam.

ST. CLAIR COUNTY.

St. Clair county is underlain by the lower Carboniferous limestones in the eastern portion, and by the coal measures in the western portion. The former are mainly composed of heavy Burlington beds which are usually very pure and white rocks with local residual pockets of pure clay that result from its chemical dissolution. The lower coal measures carry the seams of potters' clay that are so extensively worked immediately north in Henry county.

On the Gore land at Iconium (Tp. 29 N., R. XXIV W., Sec. 24) two feet of white clay were found in digging a well, at a depth of six feet. It is very plastic, fine, white to light gray in color, and seems to be residual matter from the adjacent white Burlington limestone. It also shows in the bank of a small branch from 100 and 500 feet north of the above, where it varies from one to one and one-half feet thick. About one-fourth mile east of Iconium, on the Fairfield road (Tp. 29 N., R. XXIV W., Sec. 26, NW. qr.) a very tough, plastic, light gray clay crops out by the roadside, under a capping of flint bowlders and ferruginous sandstone. It outcrops at a slightly higher level somewhat west of the previous exposure, and it evidently caps the top of the Burlington limestone. White clay is said to have been found about one-half mile west of Iconium in small shallow pits that were dug in prospecting for lead, but it has never been utilized.

ST. LOUIS COUNTY.

The fireclay that is so extensively worked in the western portion of the city of St. Louis, in the neighborhood of Cheltenham and Oak Hill can be utilized for stoneware if it is first washed to eliminate the pyrite, though it is too refractory to be desirable for this purpose. By mixing it with shale of sufficient purity this latter objection can be overcome. The shales in St. Louis county are usually too impure to be used alone for stoneware. In the western portion there are local

deposits of potters' clay that are suitable for stoneware, as the Renneberg pocket at Allenton. They are liable to be found with some frequency, if prospected with energy and experience. There are several potteries in St. Louis, but attention is confined to the coarsest kinds of earthenware as flower pots, for which is used a mixture of Cheltenham fireclay and the local loess or yellow clay.

Allenton. About one mile west of the station on the Renneberg land there is a large pocket of potters' clay in the Silurian limestone. It occurs near the base of the valley at the foot of a high hill, and a drift 12 feet long has been driven into it, which exposes a face of 6 feet of gray, sandy clay under one-half foot of soil and mixed brown clay. About 500 feet north of this drift there is a small pit that shows a mixture of chert and the same gray clay, but no other work has been done to show the magnitude of the deposit. The immediate vicinity of the limestones on all sides indicates that it is a local deposit that probably occupies an old sink-hole. A sample had the following characteristics: Color light gray, somewhat stained brown with iron. Texture massive, compact, rather hard (2.0), coarse to fine-grained. Taste, rather fat and somewhat sandy. Slacked readily and completely to one-twentieth to one-fourth of an inch granules. Pyrite was not noticeable. When ground to 20-mesh and mixed with 22.0 per cent of water it made a very plastic paste that shrunk 7.0 per cent in drying and 7.0 per cent when vitrified, giving a total shrinkage of 14.0 per cent. Briquettes of the air-dried mud gave a tensile strength of 183, and a maximum of 206 pounds to the square inch. Incipient vitrification occurred at 1,700° F., complete at 1,900°, and viscous above 2,100°. It dried rapidly, heated without cracking and burned to a gray to brown, compact body when vitrified.

An analysis gave the following results:

	Per cent.
Silica	60.07
Alumina	22.81
Water	6.48
Sesquioxide of iron	2.71
Lime	1.65
Magnesia	1.55
Alkalies	4.42
Total	99.69
Total fluxing impurities	10.33
Specific gravity	2.28

One-fourth mile west of the Renneberg pit there is a soft, plastic, potters' clay on the Wengler land.

Glencoe. Two and one-half miles northwest of Glencoe station and half a mile south of the Manchester turnpike is the Etherington

clay bank. It is on the crest of a plateau where it begins to break toward the valley of the Meramec. A face of excellent potters' clay was exposed for 80 to 100 feet along the brow of the hill. It is seven feet in thickness and is overlain by two to four feet of gravel and sand that is capped by soil. The clay is dark gray to blue in color with infrequent yellow to brown iron stains. It is massive and free from laminations, rather soft, and very plastic. It is extensively used for terra cotta, and 40 to 50 cars a year are shipped by hauling the clay down to the Glencoe lime-kilns, a distance of about one and one-half miles, where it is loaded into the cars on a spur from the main line of the Missouri Pacific railroad.

One-half mile east of the Etherington bank on the King land is a small deposit of clay that has only been partially opened and from which a moderate amount has been shipped. The Brown bank is one-fourth mile west of the Etherington. The clay is similar, but is only slightly worked. The Doyle bank is one mile from the Glencoe lime-kiln, and one-fourth mile south of the Manchester road, near the 27-mile house. A face of 18 feet of clay is exposed that varies from gray to blue-purple, or brown in color. The bottom of the clay is hard, indicating that it is an old flint clay that has weathered into a plastic condition. About 1,000 tons are said to have been shipped.

STE. GENEVIEVE COUNTY.

Local deposits or pockets of clay are found, as mentioned below, and while they may be of considerable size and sufficient to justify the erection of a pottery, they should be thoroughly tested and their magnitude carefully determined by test pits before a large outlay is incurred. Five miles southwest of Avon and one-eighth mile northwest of Coldwater creek a light gray potters' clay crops out in a wood-road under two feet of red clay and soil, at an elevation of about sixty feet above the creek. It is a soft, very plastic, fine-grained clay and is exposed for a distance of about 40 feet. About three miles east of Avon on the Count land is a fine, light gray, plastic clay that crops out on the bank of a creek.

SALINE COUNTY.

At Copeland, two miles southeast of Slater, five feet of so-called fireclay occur under the coal seam. With this thickness it seems worthy of investigation. About one-half mile south of Copeland (Tp. 51 N., R. XIX W., Sec. 18, SE qr.) at the Orr coal pit, five feet of potters' clay occur under the coal. The color is dark gray. Texture compact, massive, hard (2.0 to 2.5), coarse-grained, sandy and uniform. Taste,

lean and sandy. Slacked rapidly and completely into one-fortieth to one-tenth of an inch granules. Pyrite was present as scales, with numerous black vegetable fossils, while mica was sparingly present. When ground to 20-mesh and mixed with 17.0 per cent of water it made a plastic paste that shrunk 6.7 per cent in drying and 6.3 per cent when vitrified, giving a total shrinkage of 13.0 per cent. Briquettes of the air-dried mud gave an average tensile strength of 137, and a maximum of 163 pounds to the square inch. Incipient vitrification occurred at 1,900° F., complete at 2,100° and viscous above 2,300.° The clay dried and heated rapidly without cracking and burned to a tough, compact, brown to reddish body when vitrified.

An analysis gave the following results:

	Per cent.
Silica	50.36
Alumina	32.34
Combined water	8.25
Moisture	1.69
Sesquioxide of iron	3.90
Lime	1.04
Magnesia	0.37
Alkalies	2.01
Total	99.96
Total fluxing impurities	7.32
Specific gravity	2.48

On the Cames land (Tp. 49 N., R. XXII W., Sec. 1, NE. qr.) there are 12 feet of potters' clay under a thick shale bank, at the base of the south bluff of Finney creek. In the railroad cuts about Marshall there is exposed more or less potters' clay.

SCOTT COUNTY.

Scott county is largely underlain by the Tertiary formations, except in the northeastern corner, where the Silurian rocks appear. That elevated portion known as Crowley ridge, and the mesa or elevated area that extends from Oran to Commerce, is largely occupied by extensive, thick beds of potters' clay. The clay is very abundant although varying somewhat in quality, but the greater portion is favorable for stoneware. A very peculiar feature of this clay is its decided pink color, which is rarely seen in a clay that is as refractory as this, for it stands a temperature of 2,400° F. before yielding, while it burns to a buff color. This clay has thus far been used to a limited extent by a few small local potteries, and none has been shipped out, but when its purity is known and demand arises, it will undoubtedly be shipped to distant points, on account of its excellent quality.

Oran. One mile southeast of the town at the base of the hill along the Morley road, a bed of clay six feet in thickness crops out. It rests on a sandy shale and is overlain by four feet of soil. It is freely contaminated by white sandy spots, and an occasional seam of hard ocherous sandstone. It is a soft, sandy, dove-colored clay when dry, but dark when wet. About one and one-half miles south of this outcrop and on the same level this clay again is exposed along the roadside, but it is much purer as it is free from sand spots and sandstone, while it has a conchoidal fracture and is harder. It is at least six feet in thickness, and has only one foot of soil stripping over it. It shows again 1,000 feet southeast of the last and continues as an unbroken outcrop for over one and a half miles, while it is 10 to 15 feet in thickness.

Benton. Three-fourths of a mile west, on the south side of the Oran road, there is an outcrop of a very tough, plastic, red or pink to gray potters' clay that is similar to the one at Commerce. It is from two to three feet in thickness and is overlain by one-half foot of limonite and ochre, which latter is capped by two feet of sand and gravel.

Commerce. The bluffs of the Mississippi river at Commerce which rises from 100 to 200 feet above the river contain extensive beds of potters' clay that belong to the Tertiary period. The bluffs are capped by the yellow sandy clay of the loess formation, beneath which is a series of sands, gravels and clays. The clay is usually an excellent grade of potters', although it frequently has a decided pink color, which is due to organic matter, as it burns out and leaves a buff color. It is very seldom that such a strongly colored clay is not contaminated by an excessive amount of iron, but in the case of the Commerce clays, the rich pink color is no indication of iron whatever. A section of the Commerce bluff one-fourth mile north of the town is as follows:

		Feet.
10.	Clay, sandy, yellow (loess)	20
9.	Gravel and yellow sand	10
8.	Sand, gray, and gravel	5
7.	Gravel	2
6.	Sand, yellow, and gravel	5
5.	Gravel	2
4.	Gravel, and yellow sand	7
3.	Clay, potters', red	20
2.	Clay, potters', gray	25
1.	Sandstone (exposed)	20

The bed of clay that underlies the sands and gravels varies in color, quality and especially in thickness, but its general character is a plastic, coarse to fine grain, good grade of potters' clay. The preceeding section is well shown in the bluffs at Commerce and it con-

tinues for about three miles north to the Joe landing where the white crystalline, Cape Girardeau limestone appears and cuts it off. This same formation is characteristic of the Crowley ridge, or the Tertiary elevation that extends from this point into northeastern Arkansas. The clay has been worked on a small scale at several points in the neighborhood of Commerce for the small stoneware pottery on the bank of the river, but the complaint made is that the clay is too refractory. Most of the clay has recently been mined at the Anderson pit which is three miles west of Commerce and half a mile north of the Benton turnpike. It is six to seven feet thick and is overlain by 10 to 20 feet of gravel. It costs $1.00 ton for digging and hauling the clay to the pottery. A sample of this clay that was collected gave the following characteristics. Color light pink, with occasional white to greenish white spots, and more or less yellow to brown stains of iron. Texture massive, soft (1.0 to 1.5), rather coarse-grained and uniform. Taste, fat to finely sandy. Slacked rapidly and completely into one-fortieth to one-tenth of an inch granules. Pyrite was not noticeable, but mica was present in sparing amounts. When ground to 20-mesh and mixed with 19.0 per cent of water it made a very plastic paste that shrunk 7.5 per cent in drying and 4.0 per cent when vitrified, giving a total shrinkage of 11.5 per cent. Briquettes of the air-dried mud gave an average tensile strength of 225, and a maximum of 254 pounds to the square inch. Incipient vitrification occurred at 2,000° F., complete at 2,200°, and viscous above 2,400°.

An analysis gave the following results:

	Per cent.
Silica	71.78
Alumina	17.01
Water	8.13
Sesquioxide of iron	2.01
Lime	0.34
Magnesia	0.43
Alkalies	0.78
Total	100.48
Total fluxing impurities	3.56
Specific gravity	2.03

On the Albaugh land, immediately north of Commerce, which fronts for half a mile on the river, a red potters' clay occurs 50 to 60 above the water that has been used to a limited extent for pottery purposes, but was found too refractory. On the land of J. W. Albaugh two miles north of the town a small pit has been dug, about 500 feet from the Mississippi river, that shows a very plastic, rather fine-grained, uniform, light colored clay. It is overlain by three feet of gravel. About one mile southeast of Manning landing and four miles

northwest of Commerce there is a bank of potters' clay that was used by the small stoneware pottery that formerly existed there. It is said to be a white clay of excellent quality. On the Hillman farm, about six miles north of Commerce, and one-half mile east of Manning landing there is said to be a red to white potters' clay cropping out in a spring.

STODDARD COUNTY.

The following section is to be seen one-fourth mile east of the St. Louis, Iron Mountain and Southern railroad station at Dexter, along the sides of a small ravine:

	Feet.
5. Soil	1
4. Clay, yellow, sandy, (loess)	15
3. Gravel	5
2. Sandstone, coarse, brown	3
1. Sand and clays (exposed)	35

The lower bed of mixed clay and sand is worked in two places to supply a stoneware pottery at Dexter. A sample taken from a pit on the Kirkpatrick land one-half mile south of the station, and on the eastern slope the ridge had the following characteristics: Color light gray, with slight yellow to brown iron stains. Texture, massive, compact, soft (1.0 to 1.5), and fine grained. Taste, smooth and fat. Slacked rapidly and completely into one-thirtieth to one-fourth of an inch granules. Pyrite was not noticeable. When ground to 20-mesh and mixed with 20.0 per cent of water it gave a plastic paste that shrunk 7.8 per cent on drying and 4.0 per cent when vitrified, giving a total shrinkage of 11.8 per cent. Briquettes of the air-dried mud gave an average tensile strength of 168, and a maximum of 188 pounds to the square inch. Incipient vitrification occurred at 2,000° F., complete at 2,250°, and viscous above 2,600°.

An analysis gave the following results:

	Per cent.
Silica	68.50
Alumina	20.81
Water	7.62
Sesquioxide of iron	1.79
Lime	0.77
Magnesia	trace
Alkalies	0.53
Total	100.02
Total fluxing impurities	3.09
Specific gravity	2.13

SULLIVAN COUNTY.

Sullivan county is underlain by the coal measures which contain workable seams of fireclay under veins of coal. Some of the shales are also pure enough for stoneware, and they are worthy of investiga-

tion. At the Milan coal shaft, two feet of clay are found under the coal seam at a depth of 193 feet. One and one-half miles directly south of Milan there are ten feet of good potters' clay.

TEXAS COUNTY.

Blue potters' clay occurs four to five miles east of Plato. It is over four feet thick and is overlain by one-half foot of stripping. It is said to burn to a dark color and to a strong ware, that readily takes a salt glaze. It is used by the local stoneware potteries. A gray potters' clay also occurs on the Nagle farm, seven miles west of Licking (Tp. 32 N., R. IX W., Sec. 20), and two miles farther west, on the Ritz place. About one mile southeast of Roby (Tp. 32 N., R. XI W., Sec. 10, SE. qr.) there occurs a dark gray, plastic, soft clay that is slightly yellow-streaked with iron, and is three to four feet in thickness. It was the source of supply for the three small stoneware potteries that formerly operated in the neighborhood. It was said to be the best clay after trial of any found in the vicinity. It burned to a dark gray, strong body that glazed readily with salt. Only a small pit is visible at present, but the indications point to a large deposit that covers an extensive area.

VERNON COUNTY.

The coal measures contain seams of so-called fire clay, and at least one, if not more, beds of shale that are suitable for stoneware. Some of these seams have been utilized in the neighborhood of Deerfield, but the resources of this county in clays and shales that are suitable for stoneware have not been appreciated, and scarcely touched as yet. On the Atterbury land, about two miles south of Nevada, a fair fireclay occurs under a thin coal seam that outcrops on Birch branch; it is said to be two feet thick. On the Subree farm three and one-half miles northwest of the same place there are two and one-half feet of potters' clay; it was first thought to be a fireclay, but when tested at the Nevada Zinc works, it was found to be readily fusible.

Two and one-half miles west of Temple, a well sunk near the county road indicated a seam of at least five feet of very sandy fire or potters' clay. In the northeast quarter of section 14 (Tp. 35 N., R. XXXIII W.) there is a pit showing three feet of potters' clay. The deposit covers several acres, and makes a fair grade of earthenware.

On the Wright farm about three miles southwest of Deerfield is a bed of shale that has been used for stoneware pottery at Deerfield, Fort Scott and other places. It lies on a very gently rolling prairie, under three feet of soil and yellow clay. About one-half mile south-

STEAM POTTERY AT CLINTON.

west of the Wright bank (Tp. 35 N., R. XXXIII W., Sec. 15) on the Sprigg place is a bed of three feet of potter's clay under a coal seam. It occurs in a pasture, where the following section is exposed:

		Feet.
5.	Soil	1
4.	Gravel and yellow clay	2
3.	Shale, soft, blue	2
2.	Coal	½
1.	Clay, potters'	3

The potters' clay is a dark gray, compact, hard, sandy clay that is coarse-grained and badly iron-stained. It is washed before it is hauled to the Deerfield pottery, and pays 25 cents a ton royalty. This is undoubtedly the same seam that occurs on the Wright farm, and also one-third of a mile north, though it is said not to be as good a quality. Three miles south of Deerfield, in a well excavated on the Petrie land, on the Packbury road, is a fair potters' clay. The well is about 18 feet, deep and the potters' clay is said to be about two feet in thickness. One mile, and again at one-half mile south of Ellis, potters' clay is exposed in the gutter along the country roadside under two feet of soil and gravel. The extent of the clay is not apparent, but it is worthy of investigation on account of the ease of working. At the Hill coal mine at Moundville six feet of potters' clay occur at a depth of 25 feet under the coal. There are three feet of potters' clay at the base of Timbered Hill; also three feet on the Strong place on the Little Osage, which is probab'y the same seam. Near Carbon Center at the Hoss coal mine occur four feet of clay that may be suitable for stoneware purposes.

MANUFACTURE OF STONEWARE.

The manufacture of stoneware in Missouri is thus far confined, with a single exception, to small hand potteries. There are 49 potteries in the state, which have 57 kilns, at once showing that the industry is in an undeveloped condition. Nearly all the potteries are in out-of-the-way places that are frequently inaccessible by rail, and depend entirely upon local trade. These small potteries can successfully hold the local trade, especially away from the railroad towns, but when competing in the larger markets they are not prepared to meet the prices that are made by the steam potteries of Illinois, Indiana, and Ohio. The only successful effort that has been made to secure a large shipping business is in Henry county, where there is one large steam pottery (plate XVII) and three small hand potteries, that are worked with considerable vigor. They are favored with excellent clay while the fuel is mined almost at their very doors. At most of the potteries

the clay is washed, as but few of the clays are sufficiently free from sand and other foreign matter to be safely used without this treatment. The method of washing is simple, crude and takes a long time, while the output is limited, but it suffices for the comparatively small production.

Washing. Before washing the clay it is mined, dug and allowed to weather for considerable time. It is then usually fed to small circular vats that are from 10 to 20 feet in diameter with an excess of water in which it is exposed to the mixing and stirring action of a series of pointed teeth by dragging over it a small harrow operated by a horse. This brings the pure clay into a state of suspension, as a cream, while the sandy and other heavy foreign matter settles out as a sediment. The cream of clay is drained off, run through a fine sieve and is then allowed to settle in more or less extensive settling boxes or shallow ponds. After the clay has settled to the bottom of the vat or pond the clear water is drawn off, and the soft clay ooze remaining is allowed to slowly dry out through evaporation in the wind and sun. When it has dried to a stiff paste, it is shoveled out, and pugged in small circular vertical tempering mills by horse-power to a uniform temper. It is then stacked up in piles and stored under a wet cloth until used. As the number of settling vats or ponds is limited and as the washing can only be performed in the mild season but a small product is handled each year.

At the large steam pottery at Clinton, and in a few other cases, the clay is not washed, but is used direct from the bank after it has been once ground and tempered in a wet-pan. The use of the wet-pan permits of rapid crushing and thorough mixing of the clay in the tempering, and it is preeminently a machine for the stoneware pottery.

Moulding. The tempered clay is then moulded on a potters' wheel, by "kicking" in the hand potteries, and by power as at the Clinton steam pottery. In order to get the right amount of clay with which to mould a given article the pieces of clay are weighed out on a crude balance, before moulding. Such articles as jugs, churns, stew-pans and similar designs are moulded by the skillful manipulation of the fingers of the potter, who quickly and deftly fashions the plastic clay in any shape desired. Such simple symmetrical designs as milk crocks are made rapidly and uniformly on a "jolly" in which a plaster of Paris mould is the basis with which to secure the proper shape and size of the articles after throwing into it a piece of tempered clay of proper weight, and spinning it around on the arbor of the potters' wheel. After the ware is moulded in which the clay used is of such a temper,

that while it readily takes the shape with ease and smoothness, it is stiff enough to retain the shape if very carefully handled.

Drying. The ware is then dried with more or less care, according to the character of the clay. When the clay will stand rapid drying it is put in a dry room that is warmed by steam pipes or on shelves in the potters' room in which more or less care is exercised about draughts from doors and windows according to the sensitiveness of the ware.

Slipping. When the ware is dried, it is dipped into a cream of slip-clay if it is to be slip-glazed, or else is placed directly into the kiln, if it is to be salt-glazed. For such articles as jugs, pumps are frequently used for injecting and spraying the cream of slip-clay into the interior of the jug, while it looks downward so as to insure uniformity in the layer of the clay. The clay that is universally used by the Missouri potters for the slip-glazing is the Albany clay, that comes from Albany, N. Y. While efforts have been made to find and utilize local clays for this purpose, thus far none have been found that are satisfactory so that the Albany clay is at present exclusively used in this state. After coating the ware with the cream of Albany slip, the articles are again set on the drying shelves, to get rid of the water used in slipping, and which might cause cracking in burning if not removed.

A sample of the Albany slip clay was analyzed, with the following results:

	Per cent.
Silica	56.75
Alumina	15.47
Combine water	8.87
Moisture	0.37
Protoxide of iron	5.73
Protoxide of manganese	trace.
Lime	5.78
Magnesia	3.32
Alkalies	3.25
Total	99 54

This clay was found to shrink 6.0 per cent on air-drying and 8.0 per cent when vitrified, giving a total shrinkage of 14.0 per cent. Incipient vitrification occurred at 1,700° F., complete at 1,850° and viscous above 2,000°. It is a very fine-grained clay with a characteristic dark olive pink color. On account of the easy fusibility of the Albany clay it closes up the pores of the ware at such a low heat as to safely render in non-porous before the body of the ware has begun to soften. Being a clay and entering into the body of the ware it does not craze like most enamels, as the rate of expansion of the surface and body of

Statistics of the Stoneware and Earthenware Potteries in Missouri in 1892.

Name of pottery.	Town.	County.	Date started.	Source of clay.	Kinds of ware.	Kilns.		Production in 1891.	
						No.	Capacity, gallons.	Gallons.	Value.
N. F. Fancher	Lamar	Barton	1888	Local	Stoneware	1	1,000	10,000	$500
New Lamar Pottery	"	"	1889	"	Stoneware, flower pots	1	1,000	3,000	120
J. W. Clark	Columbia	Boone	1890	"	Stoneware	1	1,500	3,000	150
Craven Pottery	Poplar Bluff	Butler	1885	"	"	1	1,500	6,000	300
Caldwell Pottery	Caldwell	Callaway	1827	"	"	2	3,000	....	1,000
Boonville Pottery	Boonville	Cooper	1840	Calhoun, Boonville	"	2	....	....	1,000
J. M. Jegglin	"	"	1867	Boonville	"	....	....	....	4,000
Washington Clay Co	Washington	Franklin	1877	Local	Paving tiles	2	....	....	5,000
Glassir and Son	"	"	1872	"	Stoneware	1	2,000	24,000	1,440
Springfield Pottery	Springfield	Greene	1889	Billings, Hardin, Calhoun	"	1	4,000	....	4,320
Clinton Pottery	Clinton	Henry	1885	Calhoun, Clinton, Browington	"	5	27,000	1,000,000	50,000
Gulf Pottery	"	"	1891	Clinton, Calhoun	"	1	4,000	150,000	6,000
Onwider and Carr	"	"	1886	Local	"	2	....	300,000	12,000
Darby Bros	Calhoun	"	1888	"	"	2	4,000	300,000	10,000
G. A. Jegglin	"	"	1880	"	"	1	3,800	228,297	11,414
J. M. Jegglin	"	"	....	"	"	1	....	....	....
Mrs. Robine & Son	"	"	1873	"	"	1	....	25,000	1,000
Underwood & Son	"	"	1884	"	"	1	3,800	125,000	5,625
Deepwater Pottery	Deepwater	"	1891	"	Ornamental earthware	1	....	....	10,000

Shepard Pottery	Kaolin	Iron		Local	Ornamental stoneware				
Missouri Pottery Mfg. Co	Kansas City	Jackson	1888	Calhoun.	Flower pots	1		40,000	15,000
J. S. Brown & Co	Carthage	Jasper	1889	"	Stoneware	1	5,000	240,000	13,200
G. S. Purdy	Pierce City	Lawrence	1883	Local	"	2			
Wulford Pottery	Fredericktown	Madison			"				
J. Willisen	Cyclone	McDonald		Local.	"	1			500
Dananhauer and Winder	Clapper	Monroe	1885	"	"	1	4,000	50,000	
J W. Conrad	Stoutsville	"	1887	"	"	1	5,000		2,000
Middleton Pottery	Middleton	Montgomery		"	"	1			1,500
Dunnegan Pottery	Gainesville	Ozark	1868	"	"	1	1,500	15,000	1,000
J. O. Lawrence	"	"	1887	"	"	1	1,500	9,000	90
H. A. Smith	"	"	1879	"	"	1	1,500	7,500	450
Kemp and Stein	Dresden	Pettis		"	"	1		80,000	1,500
Dunnegan Pottery	Bolivar	Polk	1886	"	Stoneware, flower pots	1			
R. W. Winfree	Perry	Ralls	1876	"	Stoneware	1	2,500		
C. C. Bowen	Commerce	Scott	1850	"	"	1	2,800	60,000	3,000
Huggins & Co	Lakenan	Shelby	1870	"	"	1	5,000	60,000	3,000
McClusky Pottery	Lakenan	Shelby	1882	"	"	1	3,300	22,800	1,140
Dexter Pottery	Dexter	Stoddard	1885	"	"	1	2,500	50,000	2,000
Peters & Grubb	Dexter	"	1892	"	"	1			
Louis Gnauk	St. Louis	St. Louis		"	Flower pots, stoneware	1			5,000
St. Louis Art Pottery	St. Louis	St. Louis	1881	C. Girardeau St. Louis Glen Allen		1			1,509
Deerfield Pottery	Deerfield	Vernon	1890	Calhoun Deerfield Local	Stoneware	1	4,000	60,000	4,000
Totals						48		3,097,597	$168,749

the clay is the same. The glaze produced by the Albany slip clay has come to be standard and it not only renders the goods readily salable, but it also enables dark or other off-color potters' clays to be used, as the color is hidden by the dark enamel. If the ware is to be salt-glazed, which necessitates a clay that burns to a light color, the salt is added as in glazing a sewer pipe, at the last stage of the burning after the ware has ceased shrinking.

Burning. The burning is done in circular up-draught, down-draft and rectangular cross-draught kilns. The favorite kiln is the circular up-draft, which is made from 8 to 16 feet in diameter. On account of the thinness of the ware the water-smoking and burning does not take long, or from 12 to 36 hours for the former and 24 to 48 hours for the latter, while from 2 to 5 days are required to slowly cool off the kiln before it is opened, to avoid checking and cracking. The burning of the clay is usually regulated by trial pieces that are placed in the kiln during the setting and which are withdrawn from the holes in the wicket through the roof-ports during the burning. Wood is usually used as a fuel which avoids all trouble from specking and spattering that would arise if coal were employed from the iron in the ashes that are carried over on the ware by the draught.

Prices. The usual price realized for the finished ware of No. 1 grade at the kilns is 5 cents a gallon. It is not an uncommon thing for many of the potteries to sell a large portion of the ware at the kilns direct to those who call there for it. The moulding is usually done by contracting, at so much a gallon, which ranges from 1 to 2 cents according to the character and size of the ware. As most of the potteries are small hand establishments with a single kiln, and as the local market will not generally justify the running of the plant more than a portion of the year, the best of work is not always turned out from insufficient practice and lack of demand for the higher grades of goods. Such indifferent, intermittent work does not attract the best potters, so that much of the work is not equal to the better grades that are turned out at the large steam plants.

CHAPTER XII.

THE SHALES OF MISSOURI.

PRINCIPAL CHARACTERISTICS.

The shales are a hard, stratified, more or less rock-like class of clays. They are clays that have been deposited in water, and vary as greatly in quality and quantity as any other class of clay deposits, a their general origin they are off-shore deposits or have been formed at some distance from the borders of lakes, estuaries, or the ocean. They are usually of considerable thickness, and in most cases of very impure composition, as they have been derived from a great variety of materials. While they are among the most impure of clays, it is because of this impurity that they are usually so valuable, when used either alone, or with a mixture, for paving-brick, sewerpipe draintile, roofing-tile, terra cotta, building brick, hollow-ware, and occasionally for stoneware and refractory purposes. It is not often that they are pure enough for either refractory purposes, stoneware, or white-ware, but the possibility of being applicable to the highest class of goods, and the very great variation that occurs in the more common, less pure shales, makes it preeminently desirable to invariably test very thoroughly all occurrences of any new deposit of shale, before an opinion is passed upon its value. Thus far, the shales have been used mainly for paving-brick, for which purpose they take the lead; but their field is very broad, and the thick bodies in which they occur which is frequently above the water-line and the fact that they can often be extracted as a by-product if not as waste in coal mining, makes them worthy of much more attention than has been given to them in the past.

They nearly always make a fair grade of common brick, and it is seldom that they cannot be worked either by the dry, semi-dry, stiff-mud, or soft-mud process, after they have been finely ground. The reason for the long delay in the recognition of their great value, and the cause which deters many clay-workers from utilizing them, is the fact that they must be first very thoroughly weathered, or finely ground, before they are used; and there are still many clay-workers of limited experience, who through ignorance declare that such hard, massive,

rock-like materials cannot be utilized in the plastic arts. As the shales usually occur in high banks, with a more or less resistant, lamellar, slate-like appearance, there is no suggestion that they can be rendered tractable, even after grinding, unless mixed with a fat clay. They merge insensibly into slate on one side, which is absolutely devoid of plasticity, and into soft clay on the other. On the outcrop they frequently weather to moderate depths into soft, plastic clay and are used at a number of the stoneware potteries of Missouri under the delusion that they are potters' clay, as the workings do not go deep enough to reach the unweathered, hard, laminated material. Such weathered outcrops always work easier than the hard, unweathered portions of the bed. For particular work it will be found very desirable, if not necessary to weather the shale for one or more years, to develop its maximum plasticity and improve its homogeneity. The shales require to be blasted, on account of their toughness and hardness, though they can be handled by a heavy plow, or worked with a steam shovel, if the latter is especially designed for this severe service. The most economical method of working shales in most cases is to use explosives and preferably in the form of sand blasts, after squibbing out the hole with dynamite.

PHYSICAL PROPERTIES.

Shales usually possess little or no plasticity as they occur in the solid or laminated condition in the unweathered bank, but they become more or less plastic when ground to 10-mesh or finer. The ground shale varies greatly in plasticity and the finer it is ground the more plastic it is. As measured by the tensile strength method they vary from 50 to 250 pounds to the square inch, or from very lean to very plastic, usually between 125 to 175 pounds, or have a well developed plasticity. The amount of water required to render the ground clay plastic varies from 16.0 to 25.0 per cent, and averages about 20.0 per cent. The air-shrinkage ranges from 4.0 to 8 0 per cent and generally averages from 5.0 to 7.0 per cent. Fire shrinkage varies greatly, or from 1.0 to 10.6 per cent, usually 4.0 to 6.0 per cent. The total shrinkage is from 6.0 to 15.0 per cent, commonly from 10.0 to 13.0 per cent. In fusibility the shales are usually low, and with very few exceptions they constitute the most fusible form of clay on account of the excessive variety and amount of the impurities. Incipient vitrification occurs between 1,500° and 1,700°, F., complete vitrification between 1,700° and 1,900°, after which point they usually begin to yield and fail. They rapidly dry and heat as they are coarse-grained. They are high in density, from 2.15 to 2.60.

CHEMICAL PROPERTIES.

The shales are nearly always impure forms of kaolinite, in which the detrimental or fluxing impurities and the non-detrimental or non-fluxing impurities are both high. They range from 10.0 to 27.0 per cent in alumina, and usually contain from 20.0 to 24.0 per cent. Combined water ranges from 5.0 to 12.0 per cent and generally amounts to 6.0 to 9.0 per cent. Total silica varies from 50.0 to 75.0, and ordinarily fluctuates between 55.0 and 65.0 per cent. The iron is as a rule high, and is present in the form of pyrite in the alum shales, and as siderite in the dark shales. It ranges from 3.0 to 10.0 per cent, and generally amounts to 4.0 to 7.0 per cent calculated in the form of oxide. In the percentage of lime there is 0.5 to 2.0 per cent, but occasionally as high as 5.0 to 12.0 per cent. Magnesia ranges between 0.5 and 2.0 per cent, occasionally running up to 5.0 per cent. The alkalies are seldom as low as 2.0 per cent, commonly 3.0 to 4.0, and often as high as 5.0 per cent. The total fluxing impurities are seldom as low as 8.0 per cent, more usually they range from 10.0 to 15.0 per cent and frequently go higher.

DETAILED OCCURRENCES IN ADAIR COUNTY.

Large pure bodies of shale occur, but no deposits of large size have been observed that seemed desirable for the manufacture of vitrified brick.

Kirksville. The following section is found at the new Ivie brickyard (Tp. 62 N., R. XV W., Sec. 7, SE. qr.):

		Feet.
6.	Surface clay, plastic	2
5.	Shale, red, soft	5
4.	Interval	5
3.	Shale, yellow to green	2
2.	Sandstone and shale	10
1.	Limestone (exposed)	1

The surface clay effervesces with acids and has been found to be valueless for common brick. The red shale is said to make good common brick of excellent color. On the Dover branch, near the old Ivie brickyard (Tp. 62 N., R. XV W., Sec. 18, NW. qr.) are exposed:

		Feet.
11.	Sandstone, soft	4
10.	Shale, green, micaceous	10
9.	Interval	5
8.	Sandstone	4
7.	Shale, variegated, red and yellow	11
6.	Limestone, gray	4½
5.	Shale, dark	2
4.	Limestone, gray	1
3.	Shale, yellow to red, with calcerous nodules	4
2.	Limestone, nodular	1
1.	Shale (exposed)	2

On the Campbell and Ross land (Sec. 7, NE. qr.), the following record is given of a well bored:

		Feet.
33.	Soil and sand	7
32.	Limestone	7
31.	Shale	5
30.	Limestone	1½
29.	Shale	3
28.	Limestone	4
27.	Shale	17
26.	Limestone	3
25.	Shale	17
24.	Limestone	1¼
23.	Coal	1½
22.	Fireclay	½
21.	Shale	13
20.	Limestone	2
19.	Shale	6½
18.	Limestone	1
17.	Shale	5½
16.	Limestone	1
15.	Shale	3
14.	Limestone	2
13.	Shale, hard	12
12.	Limestone	2
11.	Shale	6
10.	Coal	3¾
9.	Fireclay	1
8.	Shale	3
7.	Limestone	1
6.	Shale	42
5.	Coal	2½
4.	Fireclay	6
3.	Shale	2
2.	Limestone	9
1.	Shale	5

Danforth. On the Quincy, Omaha and Kansas City railroad, about one mile west of the Chariton river, 20 feet of arenaceous drab shale overlie a thick coal seam that is worked by a shaft 50 feet deep.

Stahl. Four miles west of Danforth, there are 30 feet of shale overlying the coal seam that is opened by a drift above the level of the railroad. At the Beeman mine, on the banks of the Chariton river, (Tp. 63 N., R. XVI W., Sec. 3, SE. qr.) the following section occurs on the hillside above the river level, according to Broadhead:

		Feet.
22.	Slope	50
21.	Limestone	3
20	Shale, drab, soft	3
19.	Limestone, soft, brown	½
18.	Shale, buff to green	1
17.	Shale, bituminous	2
16.	Coal, shaly	1½
15.	Fireclay	1½
14.	Sandstone, green, shaly	2
13.	Sandstone, soft, greenish-gray	1

12	Shale, sandy	3
11.	Shale, blue, soft	10
10.	Sandstone and shale	35
9.	Shale, bituminous	3
8.	Coal	2½
7.	Fireclay	1
6.	Coal	1
5.	Fireclay	3
4.	Limestone, hard, blue	1½
3.	Shale, blue, sandy	¾
2.	Limestone, argillaceous	¼
1.	Sandstone, shaly, blue	15

ANDREW COUNTY.

Andrew county is occupied by the barren coal measures, which contain heavy beds of shale of varying thickness and quality. Some of these can be easily worked by drifting into the bluffs, as at Amazonia, while with others shafts are necessary to disclose larger and better beds than are exposed in the banks of the streams. Along the bluffs of the Missouri river a thick bed of shale crops out with marked persistency from the north to the south end of the county. It is well shown at Amazonia, where it is 40 feet thick, and it is probably the southward extension of this bed that thickens to 60 feet at St. Joseph, ten miles south where it is worked by several paving-brick plants. It becomes thinner toward the north and near the Holt county line it is only 15 feet thick.

The following is the section at the Amazonia bluffs:

		Feet.
6.	Limestone, blue	10
4.	Interval, probably shale	35
3.	Shale	10
2.	Limestone, blue	5
1.	Shale, olive gray (exposed)	40

A sample of the lower half of the basal bed gave the following results: Color olive gray, with occasional brown iron stainings. Texture lamellar, soft (2.0 to 2.5), fine-grained and uniform. Taste, rather lean and finely sandy. Slacked very slowly and but slightly into very coarse flakes of one-eighth to one-half of an inch in size. Pyrite and mica were present in small amounts; hydrochloric acid caused no effervescence. When ground to 20-mesh and mixed with 21.0 per cent of water it made a very plastic paste that shrunk 5.8 per cent in drying and 8.6 per cent when vitrified, giving a total shrinkage of 14.4 per cent, which is rather high. The average tensile strength of the dried mud was 137, and the maximum 153 pounds to the square inch. Incipient vitrification occurred at 1,700° F., complete at 1,850°, and viscous at 2,150°. It burned to a compact, tough, red, vitrified body, and dried rapidly and heated without cracking. It is admirably adapted for making a

good grade of vitrified brick and its location on the railroad and the Missouri river gives good shipping facilities. The overlying limestones will make it necessary to work it by the room and entry system, as they are too thick to be stripped.

At Savannah, more or less shale is found in the banks of the streams. Twenty-three feet occur on the branch two miles northeast of town, between thin beds of limestone. This shale is not uniform as it is intermixed with thin sandy layers, but if worked as a whole, would make a good grade of vitrified brick.

ATCHISON COUNTY.

This county is also underlain by the barren coal measures, in which beds of shale occur in abundance. Some of these may be worked by drifting, while shafts will disclose even larger and better beds than those now known, since the streams give but a moderate section of the strata. In the northwestern part of this district 19 feet of blue sandy shale are exposed in the bluffs of the Missouri river. On the Nishnabotna river, one and one-fourth miles above Halls bridge, 16 feet of shale are exposed at the foot of the bank of which the upper half is sandy and the lower half is argillaceous. A bed of shale 30 feet in thickness crops out in the bluffs of the same stream one mile above Pollack, the upper 10 feet being red, and the lower 20 feet very sandy, merging into sandstone. At Rockport, on Rock creek, the following sections are given by Broadhead:

		Feet.
8.	Clay, yellow (loess)	76
7.	Drift, altered	2
6.	Shale, dark drab to olive	12
5.	Interval	3
4.	Limestone	8
3.	Shale, blue and olive	1
2.	Shale, green	2
1.	Shale, green and red	2

At the King mill two miles below Rockport, on Rock creek are the following:

		Feet.
9.	Slope	30
8.	Limestone, ferruginous	2
7.	Shale, olive to drab	28
6.	Limestone, blue	1
5.	Sandstone, hard, green to brown	2½
4.	Sandstone, soft, brown	8
3.	Sandstone, blue	1
2.	Shale, blue	6
1.	Limestone, blue	1

At the Randall mill, on the Missouri bluff are:

		Feet.
10.	Loess, calcareous	81
9.	Limestone	2
8.	Sandstone, and sandy shale	22
7.	Limestone, dark, shaly	$1\frac{1}{3}$
6.	Shale, red and green	$1\frac{1}{2}$
5.	Limestone, drab	4
4.	Shale, blue and drab	28
3.	Limestone	2
2.	Shale	2
1.	Sandstone (exposed)	1

At Milton, one-fourth mile south of the town, on the west side of Tarkio creek are displayed:

		Feet.
5.	Slope	20
4.	Limestone	2
3.	Shale, soft	10
2.	Shale, hard	8
1.	Limestone (exposed)	2

The median shale bed (No. 3) was sampled and gave the following results: Color yellowish brown. Texture coarsely lamellar, soft (1.5), coarse-grained and uniform. Taste, rather lean and gritty. Slacked slowlyand imperfectly into flakes one-twentieth to one-fourth of an inch in size. Pyrite was not noticeable, but there were small irregular concretions of carbonate of lime. When ground to 20-mesh and mixed with 21.5 per cent of water it made a stiff plastic paste that shrunk 5.6 per cent in drying and 5.2 per cent when vitrified, giving a total shrinkage of 10.8 per cent. The dried mud had an average tensile strength of 127, and a maximum of 136 pounds to the square inch. Incipient vitrification occurred at 1,700° F., complete at 1,900°, and viscous at 2,050°. It burned to a dark red, dense, tough, vitrified body, and rapidly dried and heated without cracking. It should make an excellent paving-brick or terra cotta.

The lower bed (No. 2) was also sampled and gave the following results: Color light olive. Texture rather fine-grained, uniform, coarsely lamellar and rather hard (2.2 to 2.5). Taste, rather fat and slightly sandy. Slacked slowly and imperfectly to flakes of one-tenth to one-half of an inch in size. Hydrochloric acid caused slight effervesence when hot, the solution becoming yellow, indicating the presence of siderate ($FeCO_3$). When ground to 20-mesh and mixed with 22.0 per cent of water it made a stiff plastic paste that shrunk 5.2 per cent in drying and 9.9 per cent when vitrified, giving a total shrinkage of 15.1 per cent. The air-dried mud had an average tensile strength of 108, and a maximum of 123 pounds to the square inch. Incipient vitrification took place at 1,500° F., complete at 1,700°, and viscous at 1,900°. It burned to a tough, red body when vitrified, and rapidly dried and

heated without cracking. It will make a fair vitrified brick, especially if mixed with a lean clay, to reduce the shrinkage.

One-half mile north of Milton 8 feet of soft, lean, sandy shales, with considerable carbonate of lime, are exposed in the railroad cut. Borings below the track level show blue shale. The following is the section:

		Feet.
6.	Surface clay	6
5.	Limestone, blue to yellow	3
4.	Limestone, decomposed	8
3.	Shale	8
2.	Limestone, blue, shelly	2
1.	Shale, sandy (exposed)	5

Shale 12 feet thick is said to occur below this, as disclosed by a pit.

About one and one-half miles north of Fairfax and five miles south of Tarkio is the shale pit of Rankin and Wolfe that supplies the brick-yard in Tarkio. The section of this bank is:

		Feet.
10.	Clay, loess and glacial	15
9.	Shale, soft, lean, olive, with considerable carbonate of lime	8
8.	Limestone, blue to yellow	3
7.	Limestone, decomposed, yellow	1
6.	Shale, grayish to bluish	8
5.	Limestone, hard, blue	2
4.	Coal, bituminous, pyritic	$\frac{2}{3}$
3.	Fireclay, sandy and micaceous	2
2.	Shale (exposed)	1
1.	Sandstone	?

AUDRAIN COUNTY.

The coal measures which occupy the greater portion of the county are comparatively thin, but good deposits of shale have been found. In sinking coal shafts there is disclosed two to six feet of black shale above which are blue and lighter colored beds. One-half mile west of Mexico a seam of about 3 feet of shale is exposed in the cut of the Wabash railroad.

BARRY COUNTY.

The district is mainly made up of the lower Carboniferous limestones and cherts, excepting in the eastern and southeastern portions where Silurian rocks appear. A thin shale bed usually occurs between these two systems of beds but is usually too thin to be of economic value, except as observed at Seligman. This shale may locally thicken into workable deposits, but it is not likely to exceed the thickness at Seligman, where it is 8 feet. The exposure at Seligman was noticed in the cut of the Eureka Springs railroad at the town bridge crossing,

where the shale to a thickness of five feet rests on three to four feet of fat, red, weathered shale or clay, which is underlain by sandstone. This shale is also exposed in the south central portion of the county, where it is thinner. On account of the thinness of the shale and the present limited demand in this part of the state it was not tested.

BARTON COUNTY.

As the coal measures occupy all but the southeastern corner of Barton county there are numerous beds of shale. The Lamar pottery worked a shale bed at the pottery, four miles south of the town, where 6 feet of weathered soft, yellow shale is overlain by 4 feet of soft very ferruginous shale. The lower 6 feet of shale was used by the pottery. On the Waltman land is the following section:

	Feet.
6. Sandstone, shaly	8
5. Shale, black	1
4. Coal	1¼
3. Fireclay	8
2. Shale	9
1. Coal	1

At Golden City in the southeastern corner of the county, on the Kansas City, Ft. Scott and Memphis railroad, several shafts were sunk in a mound that rises to an elevation of 75 feet above the general level of the country. One of these shafts disclosed the following section:

	Feet.
5. Soil	2
4. Sandstone, white	1
3. Shale, blue	9
2. Coal	1
1. Fireclay	8

At Medoc, Broadhead gives the following section on the Little North Fork at the south county line:

	Feet.
8. Slope	28
7. Sandstone	5
6. Interval	7
5. Shale	12
4. Limerock, blue	½
3. Coal	½
2. Shale, blue, sandy	16
1. Coal (in creek)	1

At Minden a drab shale two feet thick is found over the coal in the shaft that is operated at the south end of the town. At Liberal there are under a sandstone from 6 to 10 feet of shale, immediately below which is the coal from which the former was stripped in working. Three miles northwest of Liberal on the West fork of Big Dogwood creek shale outcrops; and also at Cherry mound.

BATES COUNTY.

Bates county is entirely underlain by coal measures. Thus far the shale has only been utilized at Rich Hill, but tests made on the Foster shale indicate that it is even better in quality. On the Hacklen land (Tp. 42 N., R. XXIX W., Sec. 34) Broadhead gives the following section:

	Feet.
6. Sandstone	86
5. Shale, yellow, sandy	15
4. Shale, blue	2
3. Shale, black	½
2. Coal	½
1. Fireclay, yellow	1

Good shales also crop out on the Young land (Tp. 40 N., R. XXIX W., Sec. 24); on the Atkinson place on Panther creek (Tp. 39 N., R. XXIX W., Sec. 3); and on the Bolt farm (Sec. 14, SW. qr.)

At Rich Hill the following section occurs at the factory of the Rich Hill Fire Brick and Tile Co.:

	Feet.
7. Soil	3
6. Clay, yellow to gray	4
5. Coal	1
4. Shale, soft, gray	3
3. Shale, soft, brown	4
2. Shale, hard, black, sandy, micaceous	7
1. Coal (Rich Hill seam)	4½

The entire bank is worked down to the thick coal seam for vitrified brick. It burns to a warm, red color, and makes a good brick and tile. The thin coal seam is not removed in blasting down the shale, as it burns out of the brick without seriously injuring it.

At Foster a drab shale 6 feet thick is immediately over the coal seam, and is stripped in working the coal. A sample of this shale collected one-third of a mile south of the town, where it was 15 feet thick, gave the following results: Color light buff to olive yellow, with occasional buff (iron) and black organic streaks. Texture fine-grained, uniform and coarsely laminated. Taste, lean and somewhat gritty. Mica was present in very small disseminated scales, but pyrite was not noticeable. Slacked slowly and imperfectly into coarse lamellar grains. When ground to 20-mesh and mixed with 20.0 per cent of water it made a stiff plastic paste that shrunk 6.1 per cent in drying and 5.0 per cent when vitrified, giving a total shrinkage of 11.1 per cent. The air-dried mud had an average tensile strength of 149, and a maximum of 169 pounds to the square inch. Incipient vitrification occurred at 1,600° F., complete at 1,800°, and viscous at 2,000°. It

rapidly dried and heated, and burned to a tough, dense body with a fine red color. It is eminently adapted for paving-brick.

A chemical analysis gave the following results :

	Per cent.
Silica	55.96
Alumina	20.68
Combined water	7.82
Iron sesquioxide	8.12
Lime	1.91
Magnesia	1.96
Alkalies	3.84
Total	99.23
Total fluxing impurities	15.33
Specific gravity	2.25

At Amoret 10 feet of dark, hard, blue shale occur over the coal at a depth of 35 feet, in the shaft No. 1 of the Missouri Coal and Coke Co., one and one-half miles south of town.

BENTON COUNTY.

The eastern half of the county contains limestones and sandstones of Silurian age and most of the western half limestones of the lower Carboniferous. In the northwestern corner are a few outliers of the coal measures. At Fort Lyon (Tp. 42 N., R. XXIII W., Sec. 6) Broadhead observed the following section:

		Feet.
9.	Sandstone, light red	8
8.	Fireclay	½
7.	Coal, impure	¼
6.	Fireclay	2
5.	Shale, black to ash-colored, sandy	12
4.	Slope	3
3.	Sandstone, ferruginous	?
2.	Chert	3
1.	Slope to creek	5

BOONE COUNTY.

The greater portion of the district is made up of coal measures which have a general dip to the north and contain beds of shale. At Columbia is the following section on the bank of Hinkston creek, about two miles northeast of the town:

		Feet.
5.	Shale, soft, gray to blue	20
4.	Coal	1½
3.	Fireclay	3
2.	Conglomerate, ferruginous	6
1.	Limestone (lower Carboniferous)	5

The shale is good for paving-brick and terra cotta. At Henry station 15 feet of gray shale overlie the coal seam in the Columbia

shaft at a depth of 112 feet. At Persinger, the Goading shaft (Tp. 49 N., R. XIII W., Sec. 24) has 25 feet of gray shale overlying the coal seam, that is 60 feet deep.

BUCHANAN COUNTY.

The county is underlain by the barren coal measures and contains thick beds of shale. The thickest exposure is at the city of St. Joseph, where there are 60 feet in a single bed in the Missouri river bluffs. It thins to about 30 feet in thickness towards both the north and the south. This thick bed is utilized by the St. Joseph paving-brick plants and furnishes an unlimited quantity of shale for the demands of this section of the state. Other shale beds occur through the county, but have not thus far shown the thickness of the St. Joseph bed. Shaft sinking will develop beds that are too deep to outcrop. At St. Joseph the best development of the heavy shale bed that occurs in the bluffs of the Missouri river is to be seen at the yards of the St. Joseph Paving Brick Co., two miles south of the city, on the edge of the Missouri river bottom. The section is:

		Feet.
8.	Soil	2
7.	Loess, sandy, and slightly calcareous	20
6.	Shale, dark blue	60
5	Shale, soft, red	2
4.	Shale, soft, gray	3
3.	Limestone, brown, compact	$3\frac{1}{2}$
2.	Shale, dark, blue, sandy	6
1.	Interval, to river level	50

The principal shale bed is very uniform, rather hard, falsely bedded and very plastic when ground. Ironstone concretions (carbonate of iron) occur disseminated though it, especially in the lower part, where there are two seams 1 to 4 inches in thickness that are almost continuous. The loess stripping makes a fair grade of common brick, after the removal of which a face 65 feet in thickness is ready.

CALDWELL COUNTY.

As Caldwell county lies almost entirely within the area of the barren coal measure beds of shale of workable thickness and good quality are to be expected, but in most cases they will have to be reached by shafts, on account of depth. At the Caldwell coal shaft two miles east of Hamilton the following is exhibited at a depth of 470 feet:

		Feet.
4.	Shale, sandy (at a depth of 470 feet)	35
3.	Shale	10
2.	Coal	$1\frac{3}{4}$
1.	Shale, sandy	10

CALLAWAY COUNTY.

The northwestern portion of Callaway county is on the eastern border of the coal measures. It is therefore not likely that extensive beds of shale will be met within this area, unless in the northwestern corner. At Fulton a bed of shale 9 to 10 feet thick occurs at the Harris clay pit, at a depth of 32 feet. About a mile and a half northeast of Carrington, on the Chicago and Alton railroad there is a out-cropping of 10 feet of shale, the upper 7 feet of which is yellowish and the lower 3 feet bluish green. One and one-half miles northeast of this place as the railroad crosses Middle river the following section is observed:

	Feet.
3. Shale, yellow	30
2. Fireclay	5
1. Shale (to river)	2

Shale suitable for paving-brick occurs at Guthrie. Shales have also been noticed 6 to 8 miles west of Auxvasse (Tp. 49 N., R. X W., Sec. 23). At Steven's store (Tp. 49 N, R. XI W., Sec. 2) the following section was passed through at Oldham's coal shaft:

	Feet.
4. Clay, yellow, surface	18
3. Shale, soft	18
2. Shale, black	1
1. Coal	2½

At the Guy shaft, about one-fourth mile west of the above, 18 feet of shale were encountered at a depth of 22 feet.

CAMDEN COUNTY.

This county is underlain entirely by limestones and sandstones of the Silurian and with the exception of local pockets of limited extent and doubtful uniformity in quality, shale beds are hardly to be expected to occur. The only deposits observed were two pockets of clay in the southeast quarter of section 35, and the northwest quarter of section 36 (Tp. 37 N., R. XVII W.) The clay is similar in both pockets and is evidently derived from a shale. It is about 3 feet in thickness, soft, fine-grained, plastic, has a bluish color, and contains numerous disseminated crystals of gypsum and decomposed pyrite.

CARROLL COUNTY.

Carroll county, being underlain by the coal measures, has many shale beds, some of which are of good quality. As examples the fol-

lowing sections are given. The first is about three miles west of Miami station:

		Feet.
9.	Clay, white	5
8.	Sandstone, soft, buff to brown	7
7.	Shale, with ochery layers	37
6.	Shale, with iron concretions	7
5.	Shale	15
4.	Limestone, with hard concretions	½
3	Shale, bituminous	2
2.	Coal	½
1.	Shale, olive, ochery	8

At the Keswick quarry near Miami are 4 feet of shale overlying the coal seam at that point. On the Griffith land (Tp. 53 N., R. XXI W., Sec. 22, SE. qr.) there are 7 feet of shale over a coal seam; and it is reported that a bed 80 feet thick, consisting mainly of dark blue shale, was passed through in a well bored at this point. At Little Compton (Tp. 55 N., R. XXI W., Sec. 20, NE. qr.) is the following section:

		Feet.
4.	Shale, black	2
3.	Shale, drab	5
2.	Coal	2
1.	Clay, micaceous (exposed)	1

On the west bank of the Grand river, 5 miles south of the above 4 feet of black shale overlie the coal seam that is also underlain by shale. The following section is on Wankenda creek at the Hardwick mill, 7 miles southeast of Carrollton:

		Feet.
3.	Shale	4
2.	Shale, black	1½
1.	Coal	2

CASS COUNTY.

Shale beds are frequently exposed by the streams, but none of them have thus far been developed. Broadhead gives a number of sections of which the following are the most typical. On the forks of Big river near Strasburg are:

		Feet.
7.	Limestone, drab, fossiliferous, tough, nodular, shelly	2
6.	Shale, marlite, with calcareous nodules	6
5.	Shale, olive and purple	10
4.	Sandstone, earthy and shaly	4
3.	Shale, soft, with iron and sandstone concretions	10
2.	Shale, sandy	10
1.	Coal (exposed in creek)	1

West of Strasburg is a bed of nearly 50 feet of shale. In section 18 (Tp. 45 N., R. XXIX W.) the following section was passed through in digging a well:

		Feet.
6.	Soil and clay	7
5.	Shale, yellow, soft	15
4.	Shale, black	1
3.	Shale, blue	2
2.	Shale, bituminous	15
1.	Limestone (exposed)	1

On the western slope of the hill, on which Harrisonville is built, the following section is observed:

		Feet.
6.	Limestone, brown and gray, compact, fossiliferous	4
5.	Shale, soft and gray	5
4.	Fireclay, shaly	$2\frac{1}{2}$
3.	Shale, yellow, sandy	2
2.	Limestone, coarse, gray, fossiliferous	3
1.	Shale, sandy, yellow	25

Outcroppings of 10 to 20 feet of shale occur about 3 miles west of Harrisonville and again 1 mile further west. In the railroad cut north of Coleman 5 feet of yellow sandy shale are exposed.

CEDAR COUNTY.

Although occupied by lower Carboniferous limestones there are pockets of the coal measures of limited extent. The following section was obtained in a well on the Southerland farm on the Humansville and Stockton road (Tp. 34 N., R. XXV W., Sec. 3, NW. qr.):

		Feet.
3.	Clay, red, and soil	6
2.	Sandstone, ferruginous	14
1.	Shale, thin-bedded, dark, sandy	17

Shale occurs one mile east of Stockton in a bed 15 feet thick, resting directly on the Burlington limestone. It is a soft, plastic, fine-grained, olive-green to yellow shale, uniform, and somewhat iron-stained. This same bed also crops out two miles east of the town on the Lindley land (Tp. 34 N., R. XXVI W., Sec. 9, NE. qr.) One-half mile west of Sacville or Caplinger mill a bed of black shale 3 feet in thickness appears in a ferruginous sandstone, which at this point is over 50 feet thick. It is undoubtedly a local pocket and probably of small size. At the old Parishe coal bank (Tp. 35 N., R. XXVI W., Sec. 13, SW. qr.) is the following:

		Feet.
5.	Sandstone	2
4.	Shale	10
3.	Coal	$1\frac{1}{3}$
2.	Shale, passing into sandstone	2
1.	Coal	$1\frac{1}{2}$

CHARITON COUNTY.

Chariton county is underlain by the lower coal measures, except along the southern border, adjacent to the Missouri, where the lower Carboniferous limestones are exposed, which latter do not usually contain workable beds of shale in this portion of the state. The coal measures carry numerous beds of shale, some cf which are valuable. One bed of shale 28 feet in thickness is exposed at the old Bowman quarry, on Grand river, which contains near the base one foot of concretionary carbonate of iron, with sandstone. About 5 miles east of Salisbury, at the Gunn coal pit (Tp. 54 N., R. XV W., Sec. 31) there are 15 to 20 feet of shale over the coal seam at a depth of about 50 feet. At the Cunningham coal pit in Brunswick a bed of 6 to 8 feet of hard, gray, ferruginous shale underlies the coal seam, while the latter is capped by 5 feet of shale which is yellow and sandy toward the top and black and fissile near the base. The following is a part of the section of the deep well at Brunswick (Tp. 53 N., R. XX W., Sec. 3, SE. qr.):

		Feet.
7.	Surface soil	5
6.	Shale, blue, shelly	4
5.	Coal	1½
4.	Shale, gray	80
3.	Shale, dark chocolate colored	30
2.	Coal	1
1.	Shale, bluish gray	19

CHRISTIAN COUNTY.

The limestones and cherts of the lower Carboniferous and Silurian are the chief rocks. At the base of the former there are thick shale beds which are well exposed on the Finley river. Occasional pockets or basins of shale occur in the northwestern portion of the county, especially in the neigborhood of Billings, which appear to belong to the coal measures. The very local character of the shale beds, the strong dip, the association with sandstones and conglomerates and a general northerly trend of these seemingly isolated pockets for over 35 miles north of Billings strongly suggest that future thorough detailed work will disclose extensive deposits of clay.

One mile southeast of the railroad station at Billings, a soft, dark, drab shale has been opened in a shallow pit near the crest of a gentle hill where over 10 feet are exposed. It pitches at an angle of about 50 degrees to the east and is overlain by a coarse, brown to red sandstone that is over three feet in thickness. This shale has been used to a limited extent at the Billings pottery for terra cotta, with decided

success, as it burned to an attractive buff color, and makes a strong ware.

Two and one-half miles southwest of Billings, at the former site of the Uptegraf brickyard, another bank of shale has been opened on the north side of the St. Louis and San Francisco railroad. The shale is below the general level of the prairie in which it occurs and is worked by a pit that is below water level, so that constant pumping is necessary. The face of the cut is shown in the annexed plate XVIII. Two pits have been opened to the underlying shale the largest one being about 150 by 125 feet and over 30 feet deep, while the smaller one is about 50 by 40 feet. There is a stripping of soil from 2 to 3 feet below, which is a sandstone that on the eastern face of the large pit has a thickness of 3 feet and a local dip of about 15 degrees to the south, while on the northern face the shale dips about 25 degrees to the east. The probable thickness of the shale at this point is at least 20 feet, and likely more. A sample that was collected gave the following characteristics: Color very light gray, with abundant stainings of iron. Texture somewhat coarsely lamellar, rather soft, fine-grained, and uniform. Taste, very smooth, and slightly of alum. Slacked readily and completely to granules and flakes of one-fourth to one-fiftieth of an inch in size. Pyrite was not noticeable; mica was present in small white scales. When ground to 20-mesh it made a plastic paste with 23.0 per cent of water, which shrunk to 7.3 per cent in drying and 6.7 per cent when vitrified, giving a total shrinkage of 14.0 per cent. The dry mud had an average tensile strength of 98, and a maximum of 109 pounds to the square inch. Incipient vitrification occurred at 2,000° F., complete at 2,200°, and viscous above 2,400°. The clay rapidly dried without cracking, but needed to be slowly heated to avoid checking. It burned to a pale buff color and made an excellent quality of terra cotta, for which purpose it was used at the Keightly Manufacturing Co., at Billings.

A chemical analysis of the shale gave the following results:

	Per cent.
Silica	63.11
Alumina	23.11
Combined water	7.05
Sesquioxide of iron	1.79
Lime	0.42
Magnesia	0.70
Alkalies	3.71
Total	99.89
Total fluxing impurities	6.62
Specific gravity	2.16

CLAY COUNTY.

Clay county is underlain chiefly by the barren coal measures, excepting along the alluvial plain of the Missouri river, and contains thick and extensive shale beds. The principal occurrences at present known are situated along the Missouri river bluffs. Except where the streams have deeply eroded the formations they must be reached by shafts. A blue, calcareous shale occurs at Liberty landing and Wayne City that is 28 feet thick; it has a conchoidal fracture, and contains numerous plant impressions. The following section is shown in the bluffs one-half mile west of Missouri City, on the Wabash railroad:

	Feet.
5 Clay, yellow (loess)	30
4. Limestone	15
3. Interval	50
2. Limestone, blue	$1\frac{1}{4}$
1. Shale, soft	20

This shale ranges from gray through olive and blue to black, is sandy, and contains some iron concretions. A bed of grayish shale 5 feet thick is exposed in a cut on the Hannibal and St. Joseph railroad, at Robertson station.

CLINTON COUNTY.

The barren coal measures are the surface rocks, but as the country is mostly a level to gently rolling prairie, in which the streams have not cut deep valleys, the underlying shales are not well exposed, Shafts are necessary to reach the several shale beds within a moderate depth.

COLE COUNTY.

Cole county is underlain by limestones and sandstones which are not usually associated with thick, workable deposits of shale. Thin seams of shale occur, but they are usually too impure and too thin to be of much economic importance. A few local deposits of coal measures occur.

COOPER COUNTY.

By far the greater portion of Cooper county is underlain by limestones of lower Carboniferous age. These formations do not usually contain workable deposits of shale in this part of the state, except in the upper part. In the neighborhood of Boonville are some small outliers of the coal measures, which contain beds of shale that are the only

UPTEGRAF SHALE PIT—BILLINGS.

workable deposits known in the county. An outcrop in the vicinity of the town shows the following section:

	Feet.
5. Clay, yellow (loess)	80
4. Sandstone, brown, friable, micaceous	80
3. Limestone, hydraulic	2
2. Slope	30
1. Shale, blue and yellow, and fireclay	20

About three miles southwest of Boonville at the place at which the Missouri, Kansas and Texas railroad passes under the new county road is the following section:

	Feet.
5. Loess, sandy	12
4. Limestone, fossiliferous, yellow and gray	3
3. Shale, greenish gray	1½
2. Shale, brownish red	7
1. Shale, greenish gray, gray and red	8½

The upper ten feet of this shale was carefully sampled and the physical examination gave the following results: Color gray to reddish brown. Texture coarsely lamellar, soft (1.5), and mostly rather fine-grained. Taste, fat. Slacked slowly but completely into granules one-fiftieth to one-tenth of an inch. Pyrite, mica and sand were not noticeable. When ground to 20-mesh and mixed with 24.5 per cent of water it made a stiff, very plastic paste that shrunk 8.1 per cent in drying and 6.6 per cent in burning, giving a total shrinkage of 14.7 per cent. The tensile strength of the air-dried mud averaged 213, with a maximum of 243 pounds to the square inch. Incipient vitrification took place at 1,500° F., complete at 1,700°, and viscous above 1,900°. It burned to a compact, rather tough, dark red body, when vitrified. It dried rapidly and heated without cracking. It needed careful annealing to secure toughness, so that it probably would not make a good paving brick, but is favorable for terra cotta and press-brick.

A chemical analysis gave the following results:

	Per cent.
Silica	53.24
Alumina	23.62
Combined water	6.94
Iron sesquioxide	9 02
Lime	1 17
Magnesia	1 41
Alkalies	4 38
Total	99 78
Total fluxing impurities	15.98
Specific gravity	2.39

CRAWFORD COUNTY.

This county is entirely underlain by the limestones and sandstones of Silurian age, which do not usually contain workable beds of shale. In the cuts of the St. Louis, Salem and Little Rock railroad, between

Cuba and Steelville, an interesting series of exposures occurs, that shows a complicated intercalation of sandstone, hard, red and green shales and chert. They are usually small synclinal troughs, though much broken. The shales merge into the flint clays, but are too much intermixed with chert and are usually too thin to be of much value.

DADE COUNTY.

The limestones of the lower Carboniferous occupy the greater portion, though the eastern margin of the coal basin crosses the northwestern part of the county, and outliers or isolated areas occur in the eastern part. At one of these isolated basins about half a mile east of Everton on the McLamore land the following section was obtained in a prospect shaft:

	Feet.
6. Gravel, cherty	4
5. Shale, black, fossiliferous	11
4. Coal	1-6
3. Shale, gray	1
2. Fireclay	4
1. Sandstone	2

North of this shaft, on the bank of a small branch, are 2 feet of black shale, overlain by cherty gravel. At the Sharp coal drift about 8 miles north of Lockwood, 10 feet of dark, sandy shale, capped with 5 feet of sandstone, lies immediately over the coal seam.

DAVIESS COUNTY.

In Daviess county the barren coal measures make up the entire district, except where removed in the erosion of the Grand river valley, which cuts down to the lower coal measures. Shales may therefore be expected along the banks of the streams, while shafts will disclose workable beds. Broadhead gives several sections. About four miles below Gallatin there are:

	Feet.
6. Slope (limestone fragments)	20
5. Slope to railroad	20
4. Shale, lower part concretionary	18
3. Shale, blue	1½
2. Sandstone, blue, rough, nodular, calcareous	½
1. Sandstone (to Grand river)	18

At Gallatin:

	Feet.
18. Slope	35
17. Limestone, coarse, ferruginous, fossiliferous	1
16. Slope	2
15. Limestone, rough-looking, drab	1½
14. Shale	8½
13. Limestone, ferruginous, drab to brown	2½
12. Shale	2½
11. Slope (shaly)	23
10. Limestone, irregularly bedded, bluish-drab	4

9.	Slope	16
8.	Limestone, coarse, hard, blue	1
7.	Slope	2
6.	Limestone	19½
5.	Shale, calcareous	2
4.	Limestone, shaly	5
3.	Shale, olive	1
2.	Shale, bituminous	5
1.	Slope	?

Red shales occur on the banks of Big creek near Homan, and in the cut of the Wabash railroad at Carlow 20 feet of shale exist.

FRANKLIN COUNTY.

Ordovician limestones and sandstones which do not usually contain workable beds of shale occur throughout the district. Thin seams of greenish shale sometimes exist in the limestones but they are too thin and impure to be of much value. At Pacific, on the eastern border of the county, a bed of shale varying from 1 to 4 feet, and averaging two feet in thickness overlies the brown thin-bedded magnesian limestone at the bridge over the Meramec. In a drill hole at Sullivan on the St. Louis and San Francisco railroad 20 feet of shale were passed through at a depth of 550 feet.

GREENE COUNTY.

Greene county is made up largely of lower Carboniferous formations, except where the streams have cut down to the Silurian rocks. The former are mainly composed of limestone, as is usual in this state. but the Hannibal or Vermicular shale (of the Kinderhook) is well represented and is frequently seen in the higher portions of the county, Pockets of coal measure shales also occur, similar to those already mentioned in Christian county and like them seem to be channel deposits. Professor Shepard gives several sections. On the Moneghan farm, about 8 miles northeast of Springfield, which is regarded as the equivalent to the Hannibal shale :

		Feet.
5.	Surface clay, cherty	50
4.	Shale	10
3.	Sandstone	5
2.	Interval, probably shale or shaly sandstone	35
1.	Limestone	5

Another section which is about three miles west of Willard on the Kelso farm (Tp. 30 N., R. XXIII W., Sec. 20, SW. qr.) gives:

		Feet.
6.	Soil, red clay, with nodules of halloysite	2
5.	Limestone, dark, coarse, cherty	5
4.	Shale, reddish to greenish	3
3.	Shale, compact, bluish, with fossil plants	18
2.	Shale, black, with selenite crystals	4
1.	Shale, black, without selenite	3

The upper shale resembles the Billings deposit and is quite free from pyrite and mica. Similar beds are said to occur in the northeast quarter of section 31 of the same township and range; on the Gilmore farm three miles northwest of the Kelso land; two and one-half miles northeast of Buckley; and at several other places. On the Ray land three and one-half miles south of Republic (Tp. 27 N., R. XXIII W., Sec. 5, SE qr.) a shaft was sunk, which passed through the following:

		Feet.
7.	Soil	1
6.	Shale, red and greenish, mottled	3
5.	Shale, dark bluish green, with selenite	8
4.	Shale, black, with leaf impressions	10
3.	Limestone, blue, silicious, with selenite streaks	1¼
2.	Clay, dark carbonaceous	5
1.	Limestone, dark blue, with pyrite and selenite streaks	1½

These shales appear to be in a depression in the coal measure sandstone. A similar bed of shale that is 10 feet thick was struck in a shaft on the Cotter farm (Tp. 30 N., R. XXIII W., Sec. 23, NE. qr.) In the deep well bored at the Electric Motor plant at Springfield, on Phelps avenue and Main street, there occur 30 feet of dark drab, plastic shale at a depth of 2.0 feet.

GRUNDY COUNTY.

Grundy county is underlain by the barren coal measures, and contains several beds of shales, some of which are exposed in the banks of the streams. The bank of Grand river, at Trenton near the iron bridge at the south end of the town, shows the following section:

		Feet.
8.	Interval, lower 10 feet probably gray shale	30
7.	Limestone, brown, argillaceous	7½
6.	Interval, probably gray shale	5
5.	Coal	½
4.	Shale, soft, arenaceous, gray, with siderite concretions	15
3.	Limerock, fossiliferous, ferruginous	¼
2.	Shale, gray, soft	1
1.	Shale, black, (exposed)	½

The gray shale (No. 4) was sampled. It gave: Color dark slate (dry) to dark gray. Texture coarsely lamellar soft (1.5), coarse-grained and uniform. Taste, rather fat and gritty. Pyrite was not noticeable; mica was present in small amounts as fine scales; fossil shells and plants were sparingly present; effervesced with hydrochloric acid indicating the presence of lime. When ground to 20-mesh and mixed with 21.5 per cent of water it made a stiff plastic paste that shrunk 7.0 per cent in drying and 3.0 per cent when vitrified, making a total shrinkage of 10.0 per cent. The air-dried mud had an average tensile strength of 200, and a maximum of 221 pounds to the square

inch. Incipient vitrification took place at 1,500° F., complete at 1,750°, and viscous above 1,850°. It burned to a red to brown, compact, tough, vitrified body and rapidly dried and heated without checking. This shale is favorable for paving-brick, terra cotta and sewerpipe. A shaft 210 feet deep at Trenton went through several shale beds, one of which at a depth of 150 feet was 36 feet in thickness.

HENRY COUNTY.

Henry county is underlain by the coal measures, excepting the southeastern portion, where the limestones of the lower Carboniferous and Silurian occur. The latter do not usually carry workable beds of shale, but the former contain several. This county, which stands second in Missouri in the magnitude and variety of its clay industries, is not only making vitrified brick from its shale, but is shipping shale to Kansas City, 95 miles distant. Four manufacturing centres have already sprung up, which are located at Deepwater, Browningtou, Clinton, and Calhoun, though the shales as yet are only utilized in the two former. The excellent shipping facilities and the cheap coal that results from most of this county being underlain by workable coal seams are great advantages that promise to become of still greater importance in the future in developing the shales and potters' clays. The sketch map of the county (plate XVI) shows the points of outcrop of some of the principal shale beds that are exposed in the banks of the streams. It also shows the favorable railroad facilities, abundance of water, and the location of manufacturing centers.

Clinton. The following section occurs on the bank of Town creek one-eighth of a mile below the iron bridge at Clinton, at the buff known as the "Lover's Leap."

		Feet.
5.	Soil	2
4.	Sandstone	15
3.	Shale, gray, blue, thin-bedded, soft and iron-stained	35
2	Shale, black	1½
1.	Shale, sandy, yellow	3

The shales dip slightly to the north. A sample was collected of the thick bed (No. 3) which gave the following results: Color bluish, lamellar, and mostly very fine-grained, with some coarse sandy streaks. Taste slightly of alum, lean, and occasionally very gritty. Slacked not at all. Pyrite occurred in thin streaks one-eighth of an inch thick, with occasional scales of mica. When ground to 20-mesh and mixed with 17.0 per cent of water it made a very lean paste that shrunk 4.0 per cent in drying and 2.5 per cent when vitrified, giving a total shrinkage of 6.5 per cent. It had an average tensile strength of 35 pounds to the square inch. Incipient vitrification took place at 1,800° F., complete

at 2,000°, and viscous above 2,200°. It dried rapidly and heated without cracking and burned to a dark red body, that was lacking in strength, from the leanness of the shale. It is too lean or lacking in plasticity to be worked by itself, but makes a fair quality of paving-brick, sewer-pipe, or other coarse ware if mixed with sufficient plastic or bond clay.

An analysis of the shale gave:

	Per cent.
Silica	54.69
Alumina	25.96
Combined water	8.90
Sesquioxide of iron	4.97
Lime	0.18
Magnesia	0.15
Alkalies	3.58
Total	98.43
Total fluxing impurities	8.88
Specific gravity	2.26

At the Gilkerson ford, on Grand river, four miles south of Clinton (Tp. 41 N., R. XXVI W., Sec. 26), is the following section:

		Feet.
8	Sandstone, buff, shaly	5
7.	Shale, blue	2
6.	Coal	1-6
5.	Shale and fireclay	14½
4.	Coal	½
3.	Sandstone	3
2.	Shale, with abundant iron concretions	4
1.	Coal, in river	1½

A sample of the shale was obtained from the above section, which gave the following results: Color bluish black, with occasional brown streaks of iron. Texture lamellar, uniform and very fine-grained. Slacked not at all. Pyrite was not noticeable, but mica was abundant as very fine scales. When ground to 20-mesh and mixed with 19.0 per cent of water it made a very lean paste that shrunk 4.5 per cent in drying and 4.0 per cent when vitrified, giving a total shrinkage of 8.5 per cent.

The air-dried mud had an average tensile strength of 76, and a maximum of 81 pounds to the square inch. Incipient vitrification occurred at 1,800° F., complete at 2,000°, and viscous above 2,200°. It dried rapidly and heated without cracking, and burned to a tough, compact, dark red body.

A chemical analysis gave the following results:

	Per cent.
Silica	55.02
Alumina	24.88
Combined water	8.88
Sesquioxide of iron	5.79
Lime	0.58
Magnesia	1.50
Alkalies	3.82
Total	99.47

This clay should be mixed with a "bond" or plastic clay to give the best results as it is too lean to work satisfactorily by itself. At the Jordan coal mine about three-fourths of a mile east of Gilkerson ford there are:

		Feet.
3.	Shale, hard, blue, calcareous	15
2.	Coal	3
1.	Shale, blue, with iron concretions	9

At the Kinney coal slope, two miles southeast of Clinton, there are 10 feet of dark, fine-grained, soft shale over the coal seam. The Pitcher coal shaft three miles south of Clinton, which is 32 feet deep, gives the following section:

		Feet.
6.	Soil	2
5.	Shale, hard, bluish, sandy	25
4.	Sandstone	½
3.	Shale	1
2.	Coal	2
1.	Shale	6

At the Grant farm (Tp. 42 N., R. XXVI W., Sec. 23) about four miles north of Clinton, the section is:

		Feet.
13.	Gravel	3
12.	Clay, potters', plastic	5
11.	Limerock, hydraulic	2
10.	Shale, gray, calcareous	2
9.	Shale, black, jointed	2
8.	Limerock, hydraulic, irregular, lenticular layers, pyritiferous	1¼
7.	Coal	3
6.	Clay, potters', more or less stained, with thin non-continuous seam of coal	4
5.	Coal	1
4.	Fireclay	1
3.	Shale, soft, black, fissile	4½
2.	Coal	1¼
1.	Shale, very sandy, with Sigillaria (exposed)	1

Shale No. 3 was sampled and gave the following results: Color black to gray. Texture laminated, soft, very fine-grained and uniform. Taste, strongly of alum and somewhat fat. Slacked readily and completely to granules one-thirtieth to one-tenth of an inch in size. No pyrite was visible. When ground to 20-mesh and mixed with 22.0 per cent of water it made a stiff, plastic paste that shrunk 7.3 per cent on

drying and 5.7 per cent when vitrified, giving a total shrinkage of 13.0 per cent. The dry mud had an average tensile strength of 144, and a maximum of 159 pounds to the square inch. It burned from salmon to dark red on the surface, while the interior remained pinkish, it being difficult to obtain a uniform color. The ware rapidly dried but required to be heated rather slowly to prevent cracking.

An analysis gave:

	Per cent.
Silica	52.70
Alumina	26.86
Combined water	8.66
Sesquioxide of iron	4.49
Lime	0.57
Magnesia	0.68
Sulphuric acid	5.19
Alkalies	2.47
Total	101.62

On Field creek, near Clinton (Tp. 42 N., R. XXVI W., Sec. 29, NE. qr.) the following section occurs:

		Feet.
14.	Soil	2
13.	Limestone, hydraulic, fossiliferous	1½
12	Clay, potters', very ferruginous	2½
11.	Shale, black, jointed, with small concretions.	1
10.	Shale, black, fossiliferous	6
9.	Coal	2½
8.	Clay, potters', impure	3
7.	Coal, and impure fireclay	1
6.	Clay, potters' arenaceous, with Sigillaria	1
5.	Shale, black, fissile	5
4.	Coal	½
3.	Clay, potters', impure, sandy	3
2.	Sandstone	½
1.	Clay, varying from paint clay at top to fireclay at bottom	2

A sample of the shale No. 5 collected gave: Color blackish gray Texture laminated, uniform and very fine-grained. Taste, strongly of alum and rather lean. Slacked slowly and imperfectly to coarse flakes and granules one-tenth to one-fourth of an inch in size. Pyrite was present as minute grains one-fiftieth to one-hundredth of an inch in size, while mica occurred in small amounts as fine scales. When ground to 20-mesh and mixed with 20.0 per cent of water it made a plastic paste that shrunk 6.4 per cent in drying and 4.3 per cent when vitrified, giving a total shrinkage of 10.7 per cent. The air-dried mud had an average tensile strength of 115, and a maximum of 139 pounds to the square inch. Incipient vitrification occurred at 1,650° F., complete at 1,850° and viscous above 2,050°. It burned to a dense, tough body that had a handsome red color. It dried rapidly, but required to be slowly heated to avoid cracking. It is suitable for terra cotta, paving brick and sewerpipe.

The analysis gave the following results :

	Per cent.
Silica	55.44
Alumina	22.98
Combined water	11.95
Iron sesquioxide	5.86
Lime	0.88
Magnesia	0 69
Alkalies	3.02
Total	100.82

At the Vickers farm, about seven miles southeast of Clinton (Tp. 41 N., R. XXV W., Sec. 30, NE. qr.), in an old bluff of Grand river is the following section:

		Feet.
5.	Slope	20
4.	Sandstone, much contorted, apparently ferruginous	17
3.	Ironstone, hard	½
2.	Shale, micaceous, sandy	14
1.	Sandstone (exposed)	1

A sample of the shale gave: Color light pink to brown, with copious iron stains. Texture laminated, very fine-grained, with some sandy streaks. Taste, mostly smooth and fat, but some portions gritty. Slacked slowly into thin plates and coarse granules. No pyrite was visible; sparing scales of white mica were present; showed fine roots, indicating that it was a surface sample. When ground to 20-mesh and mixed with 23.0 per cent of water it made a stiff plastic paste that shrunk 7.6 per cent on drying and 6.7 per cent when vitrified, giving a total shrinkage of 14.3 per cent. The air-dried mud had an average tensile strength of 140, and a maximum of 157 pounds to the square inch. Incipient vitrification occurred at 1,700° F., complete at 1,900° and viscous above 2,100.° It burned to a compact, strong body, with a bright red terra cotta color. It dried rapidly, but needed some care in burning to avoid cracking. It is well adapted for paving-brick, terra cotta and sewerpipe.

An analysis gave the following results:

	Per cent.
Silica	59 06
Alumina	23.05
Combined water	6.03
Sesquioxide of iron	7.81
Lime	0.46
Magnesia	0.86
Alkalies	2.80
Total	99.57
Total fluxing impurities	11.43
Specific gravity	1.93

Deepwater. At the Blair Diamond coal shaft, one mile southeast of Deepwater there are over 17 feet of hard blue shale over the coal seam. At the Keith and Perry shaft No. 1, one-half mile northeast of

the town occur 20 feet of hard, sandy shale over the coal seam, and an underlying bed of shale. The shaft is 60 feet deep. About one mile east of Deepwater coal is worked by stripping the 15 feet of drab shale resting on the seam. One mile southeast of the town the Missouri Clay Co. works the bank of shale about 100 yards east of the factory. The section:

		Feet.
10	Soil	1
9.	Loess	6
8.	Clay, jointed, brown to gray	6
7.	Clay, gray	2
6.	Shale, yellow, sandy, coarsely laminated	5
5.	Coal	1-12
4.	Clay, potters', olive to buff, shaly	8
3.	Sandstone, soft, gray, argillaceous	2
2.	Shale, soft, gray, fat	6
1.	Shale, black	5

The shale No. 2 was sampled and gave the following results: Color bluish to light gray, with abundant yellow to brown iron stains. Texture finely laminated, and sandy in streaks. Taste, somewhat lean, and occasionally gritty. Slacked slowly but almost completely into granules one-eighth to one-fourth of an inch in size. Pyrite was not noticeable; mica scales were present in small amounts. When ground to 20-mesh and mixed with 21.0 per cent of water it made a plastic paste that shrunk 5.7 per cent in drying and 4.0 per cent when vitrified, giving a total shrinkage of 9.7 per cent. The dried mud had an average tensile strength of 124, and a maximum of 140 pounds to the square inch. Incipient vitrification occurred at 1,800° F., complete at 2,000°, and viscous above 2,200°. It dried rapidly and heated without cracking, and burned to a compact, strong, dark red body. It is well adapted for paving-brick, sewerpipe and terra cotta.

A chemical analysis gave the following results:

	Per cent.
Silica	68.54
Alumina	18.49
Combined water	4.62
Iron sesquioxide	3.38
Lime	1.08
Magnesia	0.88
Alkalies	2.87
Total	99 25
Total fluxing impurities	7.76
Specific gravity	2.32

At the Dickey Sewer Pipe Works at Deepwater is the following section:

		Feet.
4.	Soil	½
3.	Loess, or yellow clay	8
2.	Clay, very ferruginous, gray	3
1.	Shale, soft, brown	10

The section is not persistent nor uniform, and the above is an average. A sample taken gave the following results: Color bluish black to light gray, with considerable yellow to brown iron stains. Texture laminated and coarse- to fine-grained, mostly the latter. Taste, fat and gritty. Slacked very slowly and imperfectly into coarse granules. No pyrite was visible. When ground to 20-mesh and mixed with 21.0 per cent of water it made a plastic paste that shrunk 5.8 per cent in drying and 3.3 per cent when vitrified, giving a total shrinkage of 9.1 per cent. The dried mud had an average tensile strength of 100, and a maximum of 110 pounds to the square inch. Incipient vitrification occurred at 1,700° F., complete at 1,850° and viscous above 2,000°. It heated rapidly and dried without danger of cracking, and burned to a strong, compact, dark red body.

An analysis gave:

	Per cent.
Silica	60.12
Alumina	21.35
Combined water	6.32
Sesquioxide of iron	7.06
Lime	0.82
Magnesia	1.08
Alkalies	3.48
Total	99 88
Total fluxing impurities	12.09
Specific gravity	2.07

It is well adapted for paving-brick, sewerpipe and dark terra cotta. It is used for sewerpipe.

HOLT COUNTY.

The barren coal measures contain several shale beds of importance. Some of these are exposed in the banks of the streams, notably in the high bluffs of the Missouri river. Shafts would develop deeper beds. At Forest City, on the Kansas City, St. Joseph and Council Bluffs railroad, at the Plummer quarry is the following section:

		Feet.
13.	Limestone, blue	1½
12.	Shale	7
11.	Limestone	⅓
10.	Shale, gray, fat, soft, calcareous, thick-bedded	1
9.	Limestone	2
8.	Shale, blue	½
7.	Limestone, blue	2
6.	Limestone, decomposed, yellow	2
5.	Limestone, dark blue	⅔
4.	Shale (sampled, 752G)	6
3.	Sandstone	4½
2	Shale	⅔
1.	Interval, outcroppings of shaly limestone (to the railroad)	25

A sample of the shale No. 4 gave the following results: Color light greenish gray. Texture coarse-grained, somewhat sandy, coarsely lamellar, and rather soft (2.0). Taste, somewhat fat, and sandy in places. Slacked readily and completely into coarse granules one-fortieth to one-fourth of an inch in size. Pyrite was not noticeable; mica was sparingly present; considerable fine sand; not affected by hydrochloric acid. When ground to 20-mesh and mixed with 20 5 per cent of water it made a stiff, rather plastic paste that shrunk to 6.5 per cent in drying and 8.0 per cent when vitrified, giving a total shrinkage of 14.5 per cent. The air-dried mud had an average tensile strength of 190, and a maximum of 214 pounds to the square inch. Incipient vitrification occurred at 1,650° F., complete at 1,800°. It burned to a dark red, compact, tough body. It dried rather rapidly, but required to be heated very slowly to avoid checking. It is well adapted for paving and press brick, terra cotta and sewerpipe.

About one-fourth mile south of Forest City a bed of shales and shaly sandstones occurs in the railroad cut that occupies approximately the same position as the above. East of Forbes, in a railroad cut, shale is exposed for 10 feet which apparently thickens to 20 feet immediately west of the town.

HOWARD COUNTY.

Howard county is underlain by the coal measures, except along the Missouri river, where erosion has exposed the lower Carboniferous limestones. Shales are numerous, frequently in workable thickness and apparently of fair quality. At Glasgow the section on the Missouri river is:

		Feet.
12.	Clay, yellow (loess)	20
11.	Shale, black, lean, with much carbonate of lime	2½
10.	Limestone	½
9.	Shale, black	1
8.	Limestone	½
7.	Shale, black	4½
6.	Limestone, blue, fossiliferous, nodular	4
5.	Shale, greenish to drab	1
4.	Limestone, nodular, fossiliferous	2½
3.	Shale, drab	10
2	Coal	1½
1.	Shale, highly iron-stained (to river level)	6

The lower shales (Nos. 1 and 3) were similar, and when mixed together gave the following characteristics: Color light gray when dry, dark drab when damp, with slight brown iron-stainings. Texture coarsely lamellar, soft (1.5), fine-grained and uniform, with a few coarse sandy spots. Taste, rather fat, and occasionally sandy. Slacked slowly but completely into coarse granules one-fortieth to one-half of an inch

A SHALE MINE—KANSAS CITY.

in size. Neither pyrite nor mica were noticeable; sand was occasionally present in small streaks.

At the Gilven coal drift two miles west of Harrisburg, 30 feet of shale were observed overlying the coal seam.

In the vicinity of Sebree 10 feet of shale are exposed in the cut at the projected Louisiana and Missouri railroad. It shows on the east and also on the west side of the town; while a mile farther north (Tp. 50 N., R. XIV W., Sec. 8, NE. qr.) there occur 10 feet of sandy shale and 10 feet of dark shale.

IRON COUNTY.

Cambrian limestones and sandstones, through which frequently protrude knobs of porphyry and granite, cover most of the county. No workable shale beds are known or are likely to occur except as thin seams that are occasionally intercalated in the limestones. These are usually one-half to two feet thick, seldom reaching four feet and are usually green in color and highly calcareous. Such thin shale seams are to be seen in the vicinity of Bellevue and Kaolin, but are of no economic value.

JACKSON COUNTY.

Jackson county is underlain by the barren coal measures which consist largely of limestones, sandstones and some shales. Along the northern portion of the county the railroad cuts and river bluffs usually show workable beds of shale that are from 6 to 30 feet in thickness. The only shale at present worked is at the Diamond Brick and Tile works at Kansas City, but other deposits are available.

Kansas City. At the Diamond Brick and Tile plant at Diamond station on the Paola branch of the Missouri Pacific railroad a shale that is 30 feet thick at the base of a high bluff is worked by drifting. Only the middle 10 feet are used as the upper portion is too sandy, and the lower portion too calcareous. It is worked by the room and entry system, and blasted with powder (see plate XIX). A sample collected gave the following results: Color grayish blue to greenish gray, with yellow to brown iron-stains. Texture coarsely liminated, soft, very fine-grained and uniform. Taste, smooth and plastic. Slacked very slowly and imperfectly to coarse granules one-fourth to three-fourths of an inch in size. Pyrite was not noticeable; mica was present to a very slight extent as fine white scales. When ground to 20-mesh and mixed with 21.0 per cent of water, it made a plastic paste that shrunk 6.0 per cent in drying and 2.7 per cent when vitrified, giving a total shrinkage of 8.7 per cent. The air-dried mud gave an average tensile strength of 115, and maximum of 128 pounds to the square

inch. Incipient vitrification occurred at 1,500° F., complete at 1,700°, and viscous above 1,900°. It burned to a compact, tough, red to brown body, when vitrified, and dried rapidly, but needed some care in heating to avoid cracking. Specific gravity 2.37.

An analysis gave the following results:

	Per cent.
Silica	54 80
Alumina	23.73
Combined water	6.00
Sesquioxide of iron	8.67
Lime	0.64
Magnesia	2.23
Alkalies	3.80
Total	99.87

This shale has been used for several years with fairly favorable results and the quality of brick would undoubtedly be better if the cooling were not hastened from lack of kiln capacity.

A sample from a shale bed that outcrops near the base of the north bluff of Kansas City, shown in plate XX, gave the following results: Color uniform, dark bluish gray. Texture highly laminated, rather soft, fine-grained and uniform. Taste, slightly gritty. Slacked very slowly and completely to coarse flakes and granules. Pyrite was not noticeable; mica was present in small amounts as fine scales; fossil plants were present to some extent. When ground to 20-mesh it made a very plastic paste with 22.0 per cent water, that shrunk 7.0 per cent in drying and 4.7 per cent when vitrified, giving a total shrinkage of 11.7 per cent. The air-dried mud had an average tensile strength of 198, and a maximum of 226 pounds to the square inch. Incipient vitrification occurred at 1,600° F., complete at 1,750°, and viscous above 1,900°. It burned to a dense, tough, red body when vitrified, and dried rapidly and heated without cracking. It is well adapted to terra cotta on account of its fine red color; but it would be rather difficult to successfully burn a large percentage into No. 1 pavers, on account of the moderate range of 300° between the points of incipient and viscous vitrification.

An analysis gave the following results:

	Per cent.
Silica	55.75
Alumina	21.16
Combined water	8.45
Sesquioxide of iron	5.69
Lime	3 25
Magnesia	2.84
Alkalies	3.02
Total	100.16
Total fluxing impurities	14.80
Specific gravity	2.41

SHALES OF THE MISSOURIAN SERIES, IN NORTH BLUFF AT KANSAS CITY.

At Courtney (Tp. 50 N., R. XXXI W., Sec. 18, NW. qr.) there are over 20 feet of rather sandy shale at the base of the bluff near the Missouri river. At Blue Mills ferry (Tp. 50 N., R. XXXI W., Sec. 7) 25 feet of green to dark yellow-stained shale occur under 15 feet of limestone. On the Julian land (Tp. 50 N., R. XXXI W., Sec. 18, NW. qr.) 10 to 20 feet of dark greenish shale are exposed under two feet of limestone. About three and one-half miles east of Independence 15 feet of greenish blue shale are exposed in a Chicago, Alton and St. Louis railroad cut under 2 to 3 feet of limestone.

JASPER COUNTY.

The lower Carboniferous limestone and cherts are the surface formations, except in the northwestern corner, which is covered by the edge of the coal measures. The county contains numerous pockets and outliers of the latter which have been frequently encountered in the workings of the lead and zinc mines. Such pockets or local basins nearly always contain beds of shale, some of which are very thick. Most of the shales are rich in bituminous matter and are usually impure.

Joplin. At the Kibbey shaft, on the Scotia land, 4 miles southwest of Joplin, 6 to 7 feet of thinly laminated gray shale were passed through. Shale was found in sinking the Hood shaft, on the Rex mining land, where 6 feet of gray clay shale and over 5 feet of black shale occurred; the latter was 25 feet thick at a shaft adjoining. About one-half mile east on the same land, a black argillaceous shale was reached at a depth of 90 feet, which continued to the bottom of the shaft, or 24 feet deeper; it dips 10 degrees to the north. Yellow to gray shale also occurs on the Henneway lease, on the same tract, but the gray variety contains much iron as limonite concretions. At the Briggs shaft about one mile southeast of Joplin (Tp. 27 N., R. XXXI W., Sec. 17) black shale that was over 12 feet thick was encountered at a depth of 18 feet. A sample of this shale from the dump gave the following results: Color dark slate or bluish black, with some yellow to brown iron-stainings. Texture coarsely and imperfectly lamellar, soft (2.0), and rather fine-grained, with a few very thin sand layers. Taste, lean and occasionally sandy. It slacked very imperfectly, as it cracked into very coarse granules one-fourth to one-half of an inch in size. Pyrite was abundant as scales and rounded crystalline concretions, up to one-half inch in diameter. Mica was freely scattered through it, and sand occurred in streaks. When ground to 20-mesh and mixed with 21.0 per cent of water it made a stiff, plastic paste that shrunk 6.0 per cent in drying and 3.4 per cent when vitrified, giving a

total shrinkage of 9.4 per cent. The dried mud had an average tensile strength of 141, and a maximum of 148 pounds to the square inch. Incipient vitrification occurred at 1,500° F., complete at 1,700°, if the iron was retained in the form of protoxide (FeO), whereas it required 150° more if oxidized to the red or sesquioxide. Viscous vitrification occurred at 1,900°. It dried rapidly and heated without cracking.

A chemical analysis gave the following results :

	Per cent.
Silica	55.84
Alumina	22.78
Combined water	9.84
Iron protoxide	5.24
Lime	0.73
Magnesia	1.26
Alkalies	4.10
Total	99 79
Total fluxing impurities	11.33
Specific gravity	2 27

Webb City. Ten to 20 feet of black shale were noticed at the cave-in on the Nevada ground one and one-fourth miles east of the railroad station.

Carthage. Large bodies of shale have been exposed at some of the shafts of the zinc mines. At the Jasper Mining and Smelting shaft, about 600 feet north of the Missouri Pacific railroad station, 30 to 40 feet of black shales were passed through at a depth of 20 feet. This shale also occurs in a shaft 500 feet northwest, as well as in one 500 feet north. At the Lindley diggings, one and one-half miles south-east of the town, 40 feet of black shale occur. The following section is shown in the railroad cut on the spur connecting the Missouri Pacific and the St. Louis and San Francisco tracks:

	Feet.
9. Gravel, in red clay	4
8. Shale, soft and fat	6
7. Coal	½
6. Fireclay, very ferruginous	4
5. Shale, soft	2
4. Hematite, red, lean	½
3. Shale, soft, with limonite	6
2. Shale, sandy, with thin sandstone	4
1. Shale, soft	4

Two of these shale beds, numbers 1 and 8, appear to be adapted for the manufacture of good paving-brick, and may do for better grades of ware, but the others appear to be of no value.

JEFFERSON COUNTY.

Jefferson county is underlain by the limestones and sandstones of Ordovician age, which sometimes have shaly beds, as at Kimswick, Silica and Vineland. The shale is as much as 8 feet in thickness at

the latter place, but it is so contaminated with seams and concretions of limestone as to be of no value, except possibly for buff or pressed brick, if burned with very great care.

JOHNSON COUNTY.

Lying almost exclusively in the coal measures, this district contains several shale beds of workable thickness and good quality. Some of the beds are exposed along the banks of the streams and in the railroad cuts, but shafts are necessary to reach most of them.

Knobnoster. Broadhead notes the occurrence of 30 feet of shale about 6 miles southwest of Knobnoster (Tp. 45 N., R. XXIV W., Sec. 18, SW. qr.), in section 17, of the same township, 18 feet of shale, and at the head of a branch in the vicinity, a bed of 55 feet of sandy shale. On Elm fork, 5 miles southwest of Knobnoster, is a bed of shale 17 feet thick. A sample gave the following results: Color yellowish gray to dark bluish gray, with brown to yellow iron-stainings. Texture coarsely lamellar, rather hard and not uniform, varying from coarse-grained and lean to fine-grained and plastic. Taste, slightly of alum and from very gritty to smooth. Slacked slowly into one-sixteenth to three-fourths of an inch granules. Pyrite was not noticeable; mica was present to some extent and abundant in some places. When ground to 20-mesh and mixed with 20.0 per cent of water it made a plastic paste that shrunk 5.7 per cent on drying and 4.0 per cent when vitrified, giving a total shrinkage of 9.1 per cent. The air-dried mud had an average tensile strength of 124, and a maximum of 140 pounds to the square inch. Incipient vitrification occurred at 1,700° F., complete at 1,850°, and viscous above 2,050°. It burned to strong, gray, body. It heated rapidly and dried without cracking. It is suitable for sewerpipe, press-brick, draintile and probably paving-brick.

A chemical analysis gave the following results:

	Per cent
Silica	60.82
Alumina	23.98
Combined water	6.60
Sesquioxide of iron	4.37
Lime	0.46
Magnesia	0.45
Alkalies	3.16
Total	99.84

At the Boyd mill, 2 miles southwest of Knobnoster, there are three feet of grayish blue shale at a depth of 10 feet. It is coarsely and imperfectly laminated, soft, and fat and is underlain by sandy shale.

Warrensburg. About three miles south of Warrensburg on Post Oak creek (Tp. 49 N., R. XXVI W., Sec. 9, NE. qr.) 60 feet of dark sandy shale crops out.

Holden. West of the town Broadhead records the occurrence of 20 feet of thinly bedded shale with ochery concretions, and also concretions of pyrite and zinc blende. About four miles northwest, on Blackwater creek, is a bed of sandy olive shale that is 20 feet in thickness, while about one mile further northwest is a bed 30 feet thick.

LAFAYETTE COUNTY.

Lafayette county is underlain by the coal measures which contain many shale beds. Some of them are exposed in the banks of the streams and railroad cuts, but most of them have to be reached by shafts, as the following sections show. Many are favorably situated for cheap working, and their proximity to numerous coal mines should hasten their utilization, notably at Lexington where both river and rail transportation are availably.

At Lexington, Norwood gives the following section:

		Feet.
36.	Loess or yellow clay	40
35.	Sandstone, hard	2
34.	Shale, bituminous	29½
33.	Sandstone, shaly, buff	6
32.	Shale	9
31.	Coal	½
30.	Shale	4
29.	Limestone, irregularly bedded, gray and drab	4
28.	Shale, drab, green and dark	6
27.	Sandstone, hard, brown and gray	4
26.	Shale	11
25.	Limestone, drab, fossiliferous	7
24.	Shale, calcareous in upper part	6½
23.	Limestone, dull blue and yellowish drab	5
22.	Shale	1
21.	Coal	2
20.	Fireclay and shale	4½
19.	Limestone, gray and blue, thick-bedded	4
18.	Shale, blue, drab, red and yellow	21
17.	Limestone, pyritiferous, blue	1¼
16.	Shale, pyritiferous, calcareous	6
15.	Coal	½
14	Shale, drab, with calcareous nodules	4
13.	Limestone, concretionary	1⅓
12.	Shale, dark olive, calcareous	2
11.	Limestone, greenish gray	2
10.	Hard band	⅔
9.	Shale, hard, black, calcareous	5⅓
8.	Coal ("Mulky" seam)	1¾
7.	Shale, ochery	9
6.	Interval	20
5.	Limestone, ferruginous and sandy	½
4.	Clay, blue	2
3	Shale, hard, bituminous	2
2.	Fireclay	4
1.	Limestone, rough, nodular, gray, sandy	2

The section one mile west of the town, where the Missouri Pacific railroad crosses the creek is:

		Feet.
12.	Loess	40
11.	Limestone, compact, fossiliferous, light brown to gray	8
10.	Shale, blue, soft, with limestone nodules	4
9.	Shale, light gray to greenish, thin bedded and highly iron-stained	6
8.	Shale, soft, thinly bedded, purple	9
7.	Shale, blue	6
6.	Limestone, brown	2
5.	Shale, black, thinly bedded	2
4.	Shale, blue, limestone nodules	2½
3.	Coal	½
2.	Fireclay	2
1.	Slope to river	20

This section was measured on the Bell place, one-half mile west of the Bell coal mine. The upper 4-foot shale, No. 10, has too much limestone in it to be workable, the 15 feet comprised in No. 7 and 8 appear to be of good quality and a sample taken gave the following results: Color blue to gray to buff brown (dry), with slight yellow iron stains. Texture coarsely lamellar, rather hard (2.5), fine-grained and uniform. Taste, lean. Slacked slowly but completely to coarse flakes and granules one-half to one-fourth of an inch in size. Pyrite was not noticeable, but hydrochloric acid caused effervescence on a few pieces, giving a yellow color (carbonate of iron). When ground to 20-mesh and mixed with 23.0 per cent of water it made a stiff plastic paste that shrunk 6.6 per cent on drying and 9.4 per cent when vitrified, giving a total shrinkage of 16.0 per cent. The tensile strength of the air-dried mud averaged 138, with a maximum of 155 pounds to the square inch. Incipient vitrification occurred at 1,450° F., and complete at 1,600°. It burned to a compact, tough body, when vitrified that had an excellent dark red color. It heated rapidly and dried without cracking.

An chemical analysis gave:

	Per cent.
Silica	54.03
Alumina	22.50
Combined water	7.54
Sesquioxide of iron	7 90
Lime	0 85
Magnesia	2.70
Alkalies	4.12
Total	99 64
Total fluxing impurities	15.57
Specific gravity	2.33

At Waverly the following is the section:

		Feet.
13.	Interval (loess)	30
12.	Coal and shale	1
11.	Interval	37
10.	Coal	1/2
9.	Interval	15
8.	Coal	1/2
7.	Interval	6
6.	Coal	[illegible]
5.	Interval	5
4.	Coal	2/3
3.	Shale, upper 6 feet gray and sandy, lower part black and tough	7 1/2
2.	Coal	3
1.	Shale, gray to black	30

Other exposures at the Keesse mine about 4 miles southwest of Concordia disclose 6 feet of dark shale over the coal seam. At Aulville a drill-hole record discloses several thick beds of shale. At Corder a shaft put down about 97 feet gives:

		Feet.
11.	Soil, and superficial material	40
10.	Limestone, reddish, hard	5
9.	Coal	1/2
8.	Fireclay	4
7.	Shale	4 1/2
6.	Coal, impure	1
5.	Shale, blue	18
4.	Limestone	22
3.	Shale, black and fissile	1 1/2
2.	Coal (Lexington seam)	1 2/3
1.	Fireclay	1

At Higginsville, under the "bottom rock" of the Lexington coal is a shale bed which averages 5 feet in thickness, that is interspersed with fine crystals of pyrite. Vitrified brick were made of it, but they were very brittle, which may have been due to improper treatment. At Odessa a number of thick shale beds were passed through in sinking a deep drill-hole.

LIVINGSTON COUNTY.

Being underlain by the barren coal measures several shale beds occur, some of which are exposed in the banks of the streams, while others can only be reached by shafts. Broadhead notes a number of occurrences. At the Collier shaft near Cream Ridge, on the Hannibal and St. Joseph railroad (Tp. 58 N., R. XXII W., Sec. 30, SE. qr.) is the following section:

		Feet.
4.	Clay and shale	9
3.	Shale, ochery, blue, soft	8 1/2
2.	Shale, dark	16
1.	Coal	1

At Bedford there are 5 feet of shale overlying a seam of coal at a depth of about 18 feet; and three-fourths of a mile southwest, on a small creek, are 16 feet of sandy shale over another coal seam, with 12 feet of blue shale underneath. On Grand river (Tp. 56 N., R. XXI W., Sec. 29, NE. qr.) is the following section:

		Feet.
7.	Shale, green, sandy	7½
6.	Interval	2
5.	Shale, blue and olive	14
4.	Coal	1⅔
3.	Interval	1
2.	Shale, bituminous	2½
1.	Clay	2½

About one mile south of this is a bed of shale 13 feet thick that overlies the coal. Six miles north of Chillicothe, at the Cox coal mine, 44 feet of soft, gray shale overlies 18 inches of coal at a depth of 20 feet, and in the same vicinity a bed of shale 7 feet thick supplies a local pottery.

McDONALD COUNTY.

Black shale occurs in the southern portion of McDonald county that is probably of Devonian age. This is the same bed referred to in the adjoining county, but it is much thicker in this district. Winslow notes the occurrence of 50 feet of this black shale on Sugar creek, in the extreme southeastern corner of the county, and an exposure of 30 feet on Mill creek (Tp. 21 N., R. XXXII W., Sec. 30). About one-half mile below Noel 20 feet of shale are exposed in the bluffs of Elk river.

MACON COUNTY.

The underlying coal measures contain heavy beds of shale. Some of them are exposed in the bluffs of the streams which are favorable situations for cheap working. Shafts will be necessary to reach the deeper beds.

Macon City. A shale crops out in the neighborhood that is very persistent and which varies from 5 to 15 feet in thickness. It is exposed in a cut of the Hannibal and St. Joseph railroad one mile east of Macon, where it is 5 feet in thickness, and is overlain by 5 feet of shaly limestone, and 3 to 10 feet of glacial drift. At the Brown brickyard, three-fourths of a mile west of the town, it is exposed at the base of a hill where it is 12 feet thick, and is covered by heavy deposits of the drift. About one mile west of the brickyard, in the Bevier road above Duck creek, it shows about the same thickness. A sample taken from this exposure gave the following results: Color olive gray to yellow and dark yellow to brown, streaked with iron. Texture coarsely lamellar, soft (1.5), coarse-grained, and very sandy. Taste, lean and

very sandy. Slacked irregularly, a portion slowly and a portion rapidly, into flakes one-twentieth to one-fourth of an inch in size. Pyrite was not noticeable, it having oxidized, thereby freely staining yellow to brown; it did not effervesce with acid. When ground to 20-mesh and mixed with 19.0 per cent of water it made a rather lean paste that shrunk 4.5 per cent drying and 4.6 per cent when vitrified, giving a total shrinkage of 9.1 per cent. The dried mud had an average tensile strength of 57, and a maximum of 67 pounds to the square inch. Incipient vitrification occurred at 1,850° F., complete at 1,950°, and viscous above 2,100°. It burned to a fairly strong ware of good red color and heated rapidly and dried without cracking. It is well adapted for making common brick and can be used for terra cotta and draintile.

Two miles south of Macon City, at Coal hollow, it is reported that there are 10 feet of soft, fine-grained, plastic shale with some mica and very fine sand. At the Eureka shaft one mile west of Macon City there are 30 feet of shale and fireclay over the coal seam at a depth of 135 feet.

Ardmore. There are 15 feet of white, hard, sandy shale overlying the coal bed in the Kansas and Texas coal drift No. 26.

Carbon. At the bridge of the county road near Carbon, and just south of the Hannibal and St. Joseph railroad is the following section:

	Feet.
7. Limestone	3½
6. Shale, drab and buff, soft	1
5. Shale, black and fissile, with bands of black flint	5
4. Coal	2
3. Shale, drab	10
2. Coal	1
1. Clay	1

Bevier. In the Kansas and Texas coal shaft No. 42 at Bevier, there are 8 feet of drab shale, and 5 feet of white sandy shale over the coal seam at a depth of 100 feet. This white shale is often hard, and then merges into sandstone. On the Miller land 2¼ miles south of Bevier are several thick shale beds.

MARION COUNTY.

Marion county has a heavy development of shale in the southeastern portion, especially in the vicinity of Hannibal. The principal bed was formerly known as the Vermicular sandstone and shale, but more recently has been named after the leading town. This shale attains a maximum thickness of 70 feet at Hannibal, but the entire bed is not available, on account of excessive contamination with lime, and frequently arenaceous material. Portions of this shale bed are adapted for common brick, terra cotta and paving-brick. A local basin or out-

lier of the coal measures underlies the southwestern portion of the county, where purer beds of shale are found, but they are much thinner than the Hannibal bed.

The bluffs of the Mississippi river at Hannibal, which are from 150 to 250 feet high, contain a thick bed of olive green shale that crops out about 30 feet above the St. Louis, Keokuk and Northwestern railroad track. It is underlain by a thin-bedded, rough, gray limestone that over is 35 feet thick—the Louisiana limestone—and is overlain by 100 to 150 feet of extremely cherty, yellow and white limestone that is teeming with crinoid remains (Burlington). A sample of the lower 10 feet collected from near the base of "Lover's Leap," in south Hannibal, worked up into a plastic paste that burned, at 1,900° F., to a brown, compact, vitrified body, and which stood rapid heating and drying. While this sample is very encouraging as regards the quality at this point the bed changes so rapidly in quality and thickness as to make it unwise to predict as to its general characteristics; and while there is no doubt that at many places at least portions of the bed are satisfactory this should be specifically determined for each place. About two miles south of Hannibal and three-fourths of a mile west of the Mississippi river, on the old Frankford road at the Frasher place, a shaft 80 feet deep was sunk in search of zinc which is found as occasional disseminated granules in the Louisiana limestone. The upper 75 feet of this shaft passed through very sandy blue to green shale, which was undoubtedly the same shale as at "Lover's Leap" (Hannibal), though here it seemed to be of better quality. Two miles west of Hannibal, in a bluff on Minnon branch, on the Shields land (Tp. 57 N., R. IV W., Sec. 30, SE. qr.) a sample collected gave the following results: Color uniform gray. Texture coarsely lamellar, hard, very fine-grained and uniform. Taste, lean. Slacked imperfectly and very slowly, into coarse granules one-tenth to one-half of an inch in size. Mica was very sparingly present and in minute disseminated flakes one-fiftieth to one-two-hundredth of an inch in size; pyrite was not noticeable. When ground to 20 mesh and mixed with 18.5 per cent of water it made a lean paste that shrunk 4.4 per cent in drying and 5.5 per cent when vitrified, giving a total shrinkage of 9.9 per cent. The air-dried mud had an average tensile strength of 105, and a maximum of 125 pounds to the square inch. Incipient vitrification occurred at 2,000° F., and complete at 2,200°. It dried rapidly without checking, but it required to be heated rather slowly to avoid cracking. It burned to a tough, compact, buff to drab body. It is well adapted for terra cotta of a buff color.

A chemical analysis gave the following results:

	Per cent.
Silica	75.70
Alumina	9.61
Combined water	6.16
Sesquioxide of iron	1.79
Lime	2.54
Magnesia	2.11
Alkalies	2.65
Total	100.56
Total fluxing impurities	9.09
Specific gravity	2.43

MERCER COUNTY.

The barren coal measures contain beds of shale, some of which are exposed in the banks of the streams. The sections herewith given from near Princeton show the thinness of the upper beds, but shafts are likely to disclose thicker beds. About half a mile south of Princeton, Broadhead gives the following section:

		Feet.
12.	Sand (drift)	30
11.	Limestone, ferruginous	4
10.	Shale, olive, with a thin seam of siderite	11½
9.	Coal	½
8.	Shale	1½
7.	Sandstone, rough, olive	1½
6.	Clay, green	2
5.	Coal	¼
4.	Clay, dark blue	1½
3.	Sandstone, rough	3
2.	Shale, blue, sandy	?
1.	Sandstone, shaly, blue and gray	40

About three and one-fourth miles farther south are:

		Feet.
4.	Limestone	1
3.	Shale	20
2.	Slope	17
1.	Shale, sandy, to creek	8

The lower 15 feet of No. 3 was sampled and gave the following results: Color light grayish yellow, slightly iron stained. Texture coarsely lamellar, soft (1.5), rather coarse-grained and uniform. Taste, rather lean, and finely gritty. Slacked very slowly and imperfectly into coarse granules and flakes of one-twentieth to one-half of an inch in size. Pyrite was not noticeable; fossil plants were sparingly present; acids caused no effervescence. When ground to 20-mesh and mixed with 20.5 per cent of water it made a stiff plastic paste that shrunk 5.6 per cent on drying and 6.5 per cent when vitrified, giving a total shrinkage of 12.1 per cent. The air-dried mud had an average tensile strength of 93, and a maximum of 130 pounds to the square inch. Incipient vitrification occurred at 1,700° F., and complete at 1,850°. It

burned to a very tough body when vitrified, of an excellent dark, red color, and rapidly heated and dried without cracking. It would make an excellent paving-brick, press-brick, or terra cotta.

A little over a mile south of Princeton is the following section:

		Feet.
13.	Sand and clay	15
12.	Drift	5
11.	Limestone, flaggy, and fossiliferous	10
10.	Shale, dark	2½
9.	Shale, black	2½
8.	Limestone	2
7.	Shale	12
6	Limestone	4
5.	Shale, green	1
4.	Limestone, grayish green	1
3.	Shale, gray, lean	1½
2.	Limestone	¼
1.	Shale, black, slaty	8

MILLER COUNTY.

The shales of this district are confined chiefly to a few small outlying basins of coal measures. Their greatest thickness thus far observed is about 15 feet. They are associated with coal seams and rest in depressions in the magnesian limestones. Meek records some of these pockets in townships 39 and 40 north, range XIII west.

NODAWAY COUNTY.

Nodaway county is situated upon the upper coal measures which contain extensive shale beds. At the Bird coal shaft one-half mile south of Quitman is the following section:

		Feet.
8.	Soil and red clay	10
7.	Shale, blue, sandy in places	37
6.	Limestone	3
5.	Shale, drab, soft, calcareous, lean	3
4.	Limestone	3
3.	Shale, hard	3
2	Coal	1¼
1.	Fireclay	1

At the Burnett coal mine, one and one-fourth miles northwest of Burlington Junction, occurs a section on the west bluff of the Nodaway river:

		Feet.
8.	Shale, lean, fine, soft, olive	18
7.	Limestone, decomposed, yellow-stained	3
6.	Shale, olive green, soft, lean, thick-bedded, calcareous	3
5.	Limestone, decomposed	2
4.	Shale, olive, very sandy, lean, soft, thick-bedded, calcareous	5
3.	Shale, sandy, with limestone flakes	4
2.	Limestone, decomposed	1
1.	Shale	55

The upper 20 feet and the lower 10 feet of the basal bed of shale were each sampled separately. The former gave the following results: Color olive green (dry), somewhat stained brown by iron. Texture coarsely lamellar, rather hard (1.5 to 2.0), coarse-grained and uniform. Taste, lean and sandy. Slacked slowly but completely. Pyrite was not noticeable; copious effervescence was caused by cold hydrochloric acid. When ground to 20-mesh and mixed with 22.0 per cent of water it made a very plastic soft paste that shrunk 8.1 per cent on drying and 6.3 per cent when vitrified, giving a total shrinkage of 14.4 per cent. The air-dried mud had an average tensile strength of 209, and a maximum of 222 pounds to the square inch. Incipient vitrification took place at 1,600° F., complete at 1,850°, and viscous above 2,000°. It burned to a red to dark red, compact, tough body when vitrified, and heated rapidly and dried without cracking. It is well adapted for paving-brick, terra cotta and press-brick.

The sample from the lower 10 feet of the bed gave: Color dark slate (dry), and somewhat brown-stained. Texture coarsely lamellar, soft (1.5 to 2.0), rather fine-grained, and uniform. Taste, rather fat. Slacked readily and completely into flakes one-twentieth to one-fourth of an inch in size. Pyrite was not noticeable; cold hydrochloric acid caused copious effervescence. When ground to 20-mesh and mixed with 22.0 per cent of water it made a stiff plastic paste that shrunk 7.0 per cent in drying and 1.4 per cent when vitrified, giving a total shrinkage of 8.4 per cent. The air-dried mud had an average tensile strength of 211, and a maximum of 237 pounds to the square inch. Incipient vitrification occurred at 1,450° F., complete at 1,600°, and viscous above 1,750°. It burned to a tough, compact body when vitrified. If slowly water-smoked it would make a good paving-brick.

At City Bluffs, on the Nodaway river, Broadhead notes the occurrence of 76 feet of shale containing beds of ironstone. Two miles south of the Iowa state line occur 12 feet of drab shale, that is used for making building brick of good quality. Three miles northeast of Skidmore are 12 feet of blue shale, the upper part of which is sandy.

PETTIS COUNTY.

Pettis county is mainly underlain by the limestones of the lower Carboniferous age; Silurian dolomites appear in the southeastern portion, while the eastern edge of the coal basin enters the western portion. The first are not likely to contain thick beds of workable shale, but the latter contains large deposits, although only one such occurrence is mentioned. About half way between Dresden and Lamonte,

at the Newport mine, 15 to 20 feet of soft, shale overlie the coal seam which is capped by 16 feet of sandstone and shale.

PIKE COUNTY.

Pike county has a greater range of geological formations than any other county in the state. Although it is mainly underlain by the lower Carboniferous formations, the Devonian and Silurian are exposed in narrow zones along the bluffs of the Mississippi river. The lower Carboniferous which is largely limestone in this county contains a bed of shale that is exceptionally thick, or about 70 feet. The Devonian is also represented here by a thin bed of shale, while the Hudson shale has also an exceptional thickness of 60 feet. The following section is exposed in the Mississippi river bluffs at Louisiana:

		Feet.
8.	Clay, yellow	10
7.	Limestone (Burlington)	70
6.	Shale, sandy	10
5.	Shale, olive (Hannibal)	70
4.	Limestone (Louisana)	50
3.	Shale, dark, slaty (Devonian)	8
2.	Limestone (Silurian)	15
1.	Shale, blue (Ordovician), exposed	60

The heavy bed of shale (Hannibal) that outcrops along the river bluff is rather lean, olive-green in color and would make a good quality of paving brick. The lower heavy bed of blue shale (Hudson) that crops out at and above the level of the river is soft and sandy for the upper 20 feet, while the lower 30 feet are both lean and very calcareous, containing seams of limestone one-eighth to 6 inches in thickness. A sample of the upper 20 feet of this shale was collected which gave the following results: Color mainly dark, gray to greenish gray (dry), occasionally olive to yellowish green. Texture coarsely lamellar, compact, hard (2.0), coarse-grained and uniform. Taste, rather fat, and slightly gritty. Slacked readily and completely into grains one-sixtieth to one-eighth of an inch in size. Pyrite was not noticeable; cold hydrocholoric acid caused effervescence. When ground to 20-mesh and mixed with 21.0 per cent of water it made a plastic to rather lean paste that shrunk 7.3 per cent in drying and 5.0 per cent when vitrified, giving a total shrinkage of 12.3 per cent. The air-dried mud had an average tensile strength of 98, and a maximum of 114 pounds to the square inch. Incipient vitrification occurred at 1,600° F., complete at 1,800°, and viscous at 2,000°. It burned to a compact, tough red to brown body when vitrified, and dried rapidly and heated without cracking. It is well adapted for paving brick, terra cotta and press-brick.

A chemical analysis gave the following results:

	Per cent.
Silica	57.01
Alumina	24.43
Combined water	7.20
Moisture	0.43
Iron sesquioxide	5.77
Lime	1.40
Magnesia	0.49
Alkalies	3.81
Total	100.34
Total fluxers	11.47
Specific gravity	2.39

The Devonian shales, which are only 6 to 8 feet thick at Louisiana, thicken to 25 feet in the neighborhood of Bowling Green, as seen along the Chicago, Alton and St. Louis railroad where they are capped by the Louisiana limestone and are underlain by the brown Niagara limestone. On the Minor land at Bowling Green is the following section:

	Feet.
4. Slope	60
3. Shale, blue, iron-stained and somewhat calcareous	20
2. Sandstone, dark, hard	$\frac{1}{2}$
1. Limestone, argillaceous	$\frac{1}{2}$

The shale was sampled for a vertical distance of 18 feet and gave the following results: Color mainly olive green, to dark gray (dry). Texture coarsely lamellar, compact, hard (2.0 to 2.5), coarse-grained, sandy and uniform. Taste, lean and sandy. Slacked slowly, the olive completely to one-tenth to one-twentieth of an inch grains and the gray imperfectly to one-tenth to one-half inch grains. Pyrite was not noticeable; cold hydrochloric acid caused slight effervescence, though some pieces effervesced very freely; a few vegetable impressions occurred in the gray shale. When ground to 20-mesh and mixed with 17.5 per cent of water it made a plastic to rather lean paste that shrunk 6.4 in drying and 5.4 per cent when vitrified, giving a total shrinkage of 11.8 per cent. Briquettes of the air-dried clay gave an average tensile strength of 128, and a maximum of 144 pounds to the square inch.

PLATTE COUNTY.

The barren coal measures contain several good beds of shale. The following section occurs in the bluffs of the Missouri river at Weston, which indicates the character of the deposits:

		Feet.
19.	Loess	20
18.	Drift.	6
17.	Limestone, fine, blue, buff and gray	10
16.	Shale, bituminous, blue	12
15.	Limestone, dark buff to gray, marly	4
14.	Shale, bituminous, blue, with thin seams of coal	20
13.	Sandstone, soft, shaly	6
12.	Limestone, fine, gray, ferruginous	14
11.	Shale, blue, calcareous, with thin seams of coal	17
10.	Limestone, dark, buff, ferruginous	3
9.	Shale, blue	21
8.	Limestone, shaly, argillaceous	8
7.	Sandstone, shaly, calcareous	8
6.	Shale, bituminous, blue	8
5.	Limestone, hard, gray and buff	10
4.	Shale, bituminous	3
3.	Limestone, blue, hard	2
2.	Shale, blue and purple, bituminous	2
1.	Sandstone, fine-grained, calcareous	6

POLK COUNTY.

The Silurian limestones and sandstones occupy the northern and eastern portions, while the southern and western parts are covered by the lower Carboniferous limestones with a few local pockets of coal measures. These pockets nearly always carry shale, but the beds are variable in size and quality. The lower Carboniferous limestones contain a very persistent bed of shale, though it is often so highly contaminated with lime as to be of little value.

At a well dug on Lock land near Humansville, 15 feet of shale were passed through, but the upper part was evidently residual as it varied from white or yellow to brown in color and contained chert gravel. The lower 6 feet were dark, and evidently a shale. A sample gave the following results: Color slate (dry), with slight brown stainings. Texture coarsely lamellar, hard (2.0 to 2.8), uniform and fine-grained. Taste, lean. Slacked very slowly and imperfectly into coarse flakes and granules one-tenth to one-half of an inch in size. Pyrite was not noticeable; hydrochloric acid caused no effervescence. When ground to 20-mesh and mixed with 18.5 per cent of water it made a stiff plastic paste that shrunk 5.6 per cent in drying and 3.7 per cent when vitrified, giving a total shrinkage of 9.3 per cent. The air-dried mud had an average tensile strength of 88 pounds to the square inch, with a maximum of 97 pounds. Incipient vitrification took place at 1,700° F., complete at 1,900°, and viscous above 2,100°. It burned to a compact, tough, red, vitrified body, and dried rapidly and heated

without cracking. It is suitable for terra cotta, sewer-pipe and brick.

A chemical analysis gave the following:

	Per cent.
Silica	56.82
Alumina	24.48
Combined water	8.16
Iron sesquioxide	3.82
Lime	0.83
Magnesia	1.81
Alkalies	3.80
Total	99 75
Total fluxing impurities	10.26
Specific gravity	2.53

At the elevator south of the railroad station at Humansville a hole 93 feet deep was bored which, after passing through 20 feet of surface soil reached a shale similar to that in the above. On the Barnett and Fisher land about two miles southeast of the town (Tp. 35 N., R. XXIV W., Sec. 16, SE. qr.) the same shale was reported for a depth of 54 feet, after sinking 18 feet in surface material. Seven miles north of Bolivar (Tp. 32 N., R. XXII W., Sec. 8, NW. qr.) the Hannibal shales occur and are used for pottery. At Aldrich in a cut on the Clinton branch of the Kansas City, Ft. Scott and Memphis railroad is the following section:

	Feet.
5. Limestone, blue and yellow	10
4. Shale	5
3. Limestone, shaly, (occasionally)	1
2. Shale, with occasional thin limestone seam	20
1. Limestone	2

The heavy shale bed, No. 2 was sampled and gave the following results: Color bluish gray (dry), uniform. Texture coarsely lamellar to massive, compact, hard (2.5 to 3.0), rather coarse-grained and uniform. Fracture slightly conchoidal. Taste, lean and finely gritty. Slacked very slowly and imperfectly into coarse granules one-fourth to one-half of an inch in size. Pyrite was not noticeable; cold hydrochloric acid caused very copious effervescence. When ground to 20-mesh and mixed with 14.0 per cent of water it made a rather lean paste that shrunk 4.8 per cent in drying, but swelled 1.0 per cent when vitrified, giving a total shrinkage of 3.8 per cent. The cause of the swelling of the shale instead of shrinkage, when burned was due to the excessive amount of lime that it contained. The average tensile strength of the air-dried mud was 96, and the maximum 108 pounds to the square inch. Incipient vitrification occurred at 2,050° F., complete at 2,200°, quiet fusion at 2,300°. It burned to a cream-colored, compact, rather tender, vitrified body and melted easily into glass. It

rapidly heated and dried without cracking. It would make a fair buff brick, but is too tender for pavers or terra cotta.

An analysis gave the following results :

	Per cent.
Silica	46.26
Alumina	10.26
Combined water	18.02
Iron sesquioxide	2.65
Lime	11.08
Magnesia	7.84
Alkalies	3.17
Total	99.78
Total fluxers	24.74
Specific gravity	2.56

About two miles north of Sharon 20 feet of blue and yellow shale occur in the cut on the Kansas City, Ft. Scott and Memphis railroad. At Graydon Springs 5 feet of sandy shale crop out.

PULASKI COUNTY.

There is comparatively little shale or clay that occurs interstratified with the limestones. All the available deposits appear to be residuary. Near the mouth of Spring creek, at Spring Valley, Shumard reports a shale or clay that appears in the mill race which seems to possess the characters of a potters' clay. A red shaly clay also occurs over the higher parts of the county.

PUTNAM COUNTY.

Putnam county is underlain by the coal measures, and contains many beds of shale. Some of them are exposed by the streams and in railroad cuts but most of them are so deep as to necessitate shafts in order to reach them. In the railroad cut 2 miles north of Unionville are 15 feet of weathered shale, while one mile further north 10 feet of green to red, soft shale occur, and beneath this four feet of sandy shale. At the Dickinson mill, on Shoal creek, are 20 feet of shale, and 24 feet on the Ledford farm (Tp. 65 N., R. XVII W., Sec. 31, NE. qr.) About 2 miles north of Lemon station, 20 feet of weathered shale occur in the railroad cut.

RALLS COUNTY.

Ralls county is underlain chiefly by the lower Carboniferous formations, except in the east-central portion, where the Silurian extends from the Mississippi river. The Carboniferous limestones contain a heavy bed of calcareous shale that extends from Louisiana to Hannibal

along the bluffs of the Mississippi river. The Ordovician contains the better grade of shale that is about 60 feet thick at Bowling Green and Louisiana. A tongue of the coal measures also reaches into the southwestern corner of the county, and this contains beds of shale. At Saverton about 30 feet of lean, dark gray shale occur in the bluffs of the Mississippi river, which 3 miles south is 25 feet thick and very calcareous. The following section occurs near Perry (Tp. 54 N., R. VII W., Sec. 23, SW. qr.):

		Feet.
5.	Shale, black, fissile	6
4.	Coal, with parting	2¼
3.	Shale, drab and black	9
2.	Coal	1
1.	Fireclay (exposed)	1

RANDOLPH COUNTY.

The coal measures contain abundant shale beds that are usually exposed on the streams and the railroad cuts. One seam, the upper Huntsville, is found throughout the county, and is rarely as thin as 15 feet, is usually 30 feet and occasionally as high as 60 feet. This shale is readily accessible at many points by open pits, but it varies greatly in character, though with a prevalent tendency to be very lean. It has an olive gray color and overlies the principal coal seam. There is a second shale bed almost as persistent as the preceding, but it is not so thick and it is less frequently accessible by open pits, though it is more uniform in quality. A shale 60 feet thick also is worked at Moberly, with very successful results. This seam may be the equivalent of the upper Huntsville seam. Although the shales are at present only utilized at Moberly, the county is rich in variety and quantity. They are destined to be of great value in the future, with the accompanying coal seams to furnish cheap fuel.

Jacksonville. A bed of shale that is 5 to 6 feet thick crops out in many of the ravines in the neighborhood, though it is often weathered to a soft plastic potters' clay. When not weathered it is a thin-bedded, olive gray to yellow shale, and is usually capped by 3 to 10 feet of drift. It shows in the Huntsville road about one mile southwest of the town; and also in a small branch about one and one half miles northeast; and again about one-half mile west, just south of the point at which the College Mound road turns off from the Huntsville road. About three miles southwest of Jacksonville, and one-fourth mile east of the Penny bridge, over the east fork of the Chariton river, several shales crop out along the hillside, the lowest and thickest of which,

known as the "Pottery Hill" seam was formerly used by the pottery that occupied this site. The following is the section:

		Feet.
19.	Clay, yellow	5
18.	Shale, yellow	8
17.	Limestone, brown	5
16.	Shale, black	2
15.	Coal	1¼
14.	Fireclay	1
13.	Limestone	3
12.	Shale, yellow to gray	3
11.	Sandstone	3
10.	Coal	3
9.	Fireclay	1
8.	Limestone	4
7.	Interval (shaly sandstone)	12
6.	Limestone, yellow	½
5.	Interval (shale?)	5
4.	Shale (Pottery bed)	15
3.	Shale black	6
2.	Coal (lower Ardmore seam)	1½
1.	Fireclay	1

About one mile west of Jacksonville, and 2,000 feet east of the Chariton river, a yellow shale, that is 12 feet thick, crops out along the roadside. It is overlain by 3 to 8 feet of drift. It lies at the base of a hill 30 to 40 feet above the level of the creek, and is very favorably situated for drift mining. It is very sandy, especially in the lower part, where it merges into a shaly sandstone. It is olive green in color and is freely stained with iron.

Darksville. Near the middle fork of the Chariton river (Tp. 55 N., R. XV W., Sec. 19) 10 feet of sandy shale rest on the coal seam, which latter is worked by drifts along the hillside.

Thomas Hill. On the east bank of the Middle fork of the Chariton river the following section is exposed:

		Feet.
15.	Clay, yellow	40
14.	Limestone	8
13.	Shale, black	4
12.	Limestone, brown, fossiliferous	10
11.	Shale, black	15
10.	Coal	1½
9.	Fireclay, gray	5½
8.	Shale, gray (No. 3)	8
7.	Limestone, brown, fossiliferous	8
6.	Shale, soft, brown (No. 2), in bed of Chariton river	8
5.	Sandstone	12
4.	Shale (No. 1)	20
3.	Coal	4
2.	Clay	1½
1.	Limestone	1

The portion of the section below the river level was obtained from a shaft 49 feet deep that was sunk near the river, to the thick coal seam. The lowest or No. 1 shale is perhaps the upper Huntsville bed. The No. 2 or brown shale is soft and plastic but it is at this point at the river level which is subject to a rise of over 10 feet. No. 3 or the soft gray shale is so pure, fine-grained, fat and plastic that it may be suitable for stoneware.

Cairo. Three miles west of Cairo (Tp. 54 N., R. XIV W., Sec. 5) 16 feet of drab shale rest on 4 feet of coal.

Huntsville. At the shaft of the coal mine at Huntsville station, near the Wabash railroad, is the following section:

		Feet.
8.	Clay, yellow	14
7.	Limestone	8
6.	Conglomerate	3
5.	Sandstone	7
4.	Shale (upper Huntsville)	30
3.	Coal	3½
2.	Fireclay	2
1.	Limestone	1

The shale No. 4 of this section is designated as the upper Huntsville bed. It is exposed in the railroad cut near the Huntsville station, where it is over 20 feet thick, as a soft, gray shale that is favorably exposed for quarrying or drift-mining. It is exposed at the hillside at the Stuart and Robinson mine at the southwest end of the town, where it rests on the 4 feet of coal. It is very favorably located for open working at this point as it is 25 feet thick, and is covered by only a few feet of stripping. A sample from this bed gave the following results: Color variable, mainly a light yellow to gray or brown. Texture coarsely lamellar, hard, and fine- to coarse-grained. Taste, lean and very sandy. Slacked slowly into coarse flakes and granules. Pyrite was not noticeable; but sand was very abundant in some portions. No effervescence occurred with hydrochloric acid. When ground to 20-mesh and mixed with 19.0 per cent of water it made a somewhat lean paste that shrunk 5.5 per cent in drying and 6.5 per cent on vitrifying, giving a total shrinkage of 12.0 per cent. The air-dried mud had an average tensile strength of 99, and a maximum of 122 pounds to the square inch Incipient vitrification occurred at 1,800° F., complete at 1,950°, and viscous above 2,100°. It heated rapidly and dried without cracking and burned to a compact tough body of fine red color. It is an excellent terra cotta clay, and probably would make a good paving brick.

An analysis gave the following results:

	Per cent.
Silica	56.86
Alumina	17.97
Combined water	6.96
Moisture	2.45
Iron sesquioxide	9.35
Lime	1.67
Magnesia	1.12
Alkalies	2.61
Total	98.99
Total fluxing impurities	14.75
Specific gravity	2.34

This upper shale crops out about one and one-half miles northwest of Huntsville on the Keytesville road along the bluff of the East fork of the Chariton river, where the following section is shown:

		Feet.
8.	Clay, yellow	15
7.	Shale, sandy (upper Huntsville)	30
6.	Coal	4
5.	Fireclay, gray	1½
4.	Limestone, brown, compact	1½
3.	Shale, blue to gray (lower Huntsville)	20
2.	Limestone, brown	2
1.	Shale, black	5

A sample of the lower shale bed, or No. 3, of the above section which has been designated as the lower Huntsville is a soft, blue to gray shale that gave the following results: Color gray to olive (dry), and heavily stained yellow to brown by iron, when wet dark gray to blue. Texture lamellar, soft, rather fine-grained and uniform. Taste, fat and slightly sandy. Slacked readily to flakes and granules of one-thirtieth to one-tenth of an inch in size. It was not affected by hydrochloric acid and pyrite was not noticeable. When ground to 20-mesh and mixed with 21.0 per cent of water it made a plastic paste that shrunk 7.8 per cent in drying and 5.8 per cent when vitrified, giving a total shrinkage of 13.6 per cent. The air-dried mud had an average tensile strength of 168, and a maximum of 180 pounds to the square inch. Incipient vitrification occurred at 1,700° F., complete at 1,850°, and viscous above 1,950°. It burned to a compact, tough, red body when vitrified. It dried rapidly without checking, but required to be heated rather slowly to avoid cracking. It is suitable for terra cotta, paving-brick and sewerpipe.

A chemical analysis gave the following results:

	Per cent
Silica	58.42
Alumina	25.36
Combined water	5.74
Moisture	1.41
Iron sesquioxide	6.61
Lime	1.12
Magnesia	1.67
Alkalies	2.97
Total	100.51
Total fluxing impurities	9.58
Specific gravity	2 15

The lower shale is very plastic, and somewhat difficult to burn, and would work much safer and better if mixed with the upper lean shale which at this exposure is very sandy. The mixture would make an excellent terra cotta and probably a good grade of paving or stock brick.

About one mile west of Huntsville the upper shale crops out on the hillside along the county road, where it is 20 feet thick, soft and plastic, and is overlain by 10 feet of shaly sandstone. The upper shale is again exposed 5 miles northwest of Huntsville, on the east bank of Dark creek, where it is about 25 feet thick, and is capped by over 2 feet of gray limestone. It is very sandy and ferruginous at this exposure. It is also exposed in the ravine one-fourth mile north of Huntsville, where it is 25 to 30 feet thick, and very lean and sandy. It is here capped by 2 feet of limestone that is covered by 8 feet of sandstone. About two and one-half miles north of the town it crops out along the roadside, where it is over 20 feet thick and soft and plastic. On the bank of Morrow creek, one and three-fourths miles north, the same shale seems to be over 30 feet thick. The following section shows about 4 miles north of Huntsville (Tp. 54 N., R. XV W., Sec. 11) where the coal seam is about 20 feet above the creek bed:

	Feet.
7. Clay, yellow	10
6. Shale, sandy	30
5. Coal (Huntsville seam)	4
4. Fireclay	1
3. Limestone	2
2. Shale, soft, gray	8
1. Limestone (exposed)	6

The upper shale is here very sandy and merges into a shaly sandstone, while the lower shale is very fat and plastic. About three miles south of Huntsville at the point at which the county road crosses Sweet Spring creek (Tp. 53 N., R., XV W., Sec. 12, SW., qr.) a bluish gray, very sandy shale crops out for 20 feet above the creek bottom. It is over-

lain by a coarse, ferruginous sandstone that is 10 to 25 feet thick, on which rests a mantle of 2 to 5 feet of drift. The shale is very uniform, lean, sandy, and coarse-grained.

Moberly. The shale bank of the Moberly Brick, Tile and Earthenware Co. is about one mile southwest of the town and one and one-eighth miles south of the factory, with which it is connected by a narrow gauge railroad. The shale crops out along a hillside in a face 30 feet in height. The total thickness of the bed is 60 feet. The shale is uniform, of a grayish blue color, is rather hard, tough, and very coarsely lamellar. It is rather rich in fossil ferns and is freely interspersed with "nigger-heads" or more or less spherical concretions of siderite and limestone. These concretions are hard and tough, and sometimes contain neuclei of calcite, manganite, sphalerite and pyrite; they are rejected and thrown to one side in working the bank, from the difficulty found in crushing them, rather than from any detrimental effect upon the brick. The shale is worked by quarrying, and broken with powder by sand blast, after squibbing with dynamite. A sample of this shale that was collected gave the following results: Color bluish gray. Texture coarsely lamellar, hard, rather coarse-grained and uniform. Taste, lean and finely gritty. Slacked very slowly and imperfectly into granules one-tenth to one-half of an inch in size. Pyrite was not noticeable; mica was present in small amounts; hydrochloric acid caused appreciable effervescence when hot, giving a yellow solution (iron carbonate). When ground to 20-mesh and mixed with 18.5 per cent of water it made a rather lean paste that shrunk 5.2 per cent in drying and 3.5 per cent when vitrified, giving a total shrinkage of 8.7 per cent. The air-dried mud had an average tensile strength of 92, and a maximum of 104 pounds to the square inch. Incipient vitrification occurred at 1,850° F., complete at 2,050°, and viscous above 2,250°. It burned to a red, compact, tough, vitrified body, and dried rapidly and heated without cracking.

An chemical analysis gave the following results:

	Per cent.
Silica	65.00
Alumina	19.30
Combined water	5 51
Moisture	1.03
Iron sesquioxide	4.91
Lime	1.40
Magnesia	0.40
Alkalies	2.60
Total	100.16
Total fluxing impurities	9.31
Specific gravity	2.41

It makes a superior quality of paving-brick and is also well adapted for terra cotta and press-brick.

At the shale bank of the Star Brick Co., one and one-half miles west of Moberly, the same shale is worked into pressed brick by the dry-press process. Fifteen feet of shale are exposed in the bank on the hillside 200 yards south of the works. It is said to have a total thickness of 50 feet. The shale is softer, finer and more argillaceous than at the other pit, and it burns to a fine dark red color. It is rather fat, highly laminated and bluish to yellowish gray in color.

Renick. At this point 4 feet of coal are worked by a shaft 100 feet deep and there are 15 feet of gray shale immediately over the coal.

Eliot. Coal is worked by a shaft 146 feet deep; it is overlain by 13 feet of shale.

Higbee. Drill-holes and excavations disclose abundant deposits of good shale. The thick shale bed over the main coal seam is very persistent in the different coal shafts near Higbee, which reach it at a depth of 100 to 140 feet.

Yates. About three miles northeast (Tp. 53 N., R. XV W., Sec. 33, NE qr.) on a small creek on the east side of the county road, the following section is exposed:

		Feet.
6.	Clay, yellow, glacial	10
5.	Shale, soft, blue	10
4.	Coal	1
3.	Fireclay	½
2.	Limestone, nodular	4½
1.	Shale, lean, gray	10

About four miles north (Tp. 53 N., R. XV W., Sec. 28, NE qr.) a section exposed in a washing by the road three-fourths of a mile north of Silver creek gives:

		Feet.
5.	Clay, yellow, glacial	10
4.	Coal	1¼
3.	Fireclay	1
2.	Limestone	10
1.	Shale, gray to blue	20

RAY COUNTY.

Ray county contains extensive shale beds. Some of them are exposed in the banks of the streams and railroad cuts, but most of them are so deep as to require shafts in order to reach them. In the bluffs of the Missouri river, one and one-half miles west of Camden, is exposed the following section:

		Feet.
4.	Shale, drab, sandy	15
3.	Limestone, nodular	½
2.	Shale, green	3
1.	Limestone (exposed)	1

At the Hughes coal mine about one mile south of Richmond (Tp. 52 N., R. XXVII W., Sec. 32, SW. qr.) is a bed of 25 feet of red and blue shale at a depth of 18 feet. At the Swanwick shaft occur 16 feet of red shale at a depth of 3 feet, and a bed of 22 feet of blue shale at a depth of 52 feet. At the Sander well, 802 feet deep, west of Richmond (Tp. 52 N., R. XXIX W., Sec. 34, NE. qr.) Broadhead gives the following section, showing the extent of the shale deposits:

		Feet.
35.	Sandstone, black, bituminous, impregnated with oil	5
34.	Limestone, light greenish	40
33.	Shale, dark, ash, sandy	80
32.	Sandstone, dark gray, coarse, bituminous	28
31.	Coal	5
30.	Limestone, drab	6
29.	Shale, greenish drab	16
28.	Limestone, coarse, dark gray	2
27.	Shale, variegated green, bituminous, and calcareous	8
26.	Fireclay, ash-blue, highly calcareous	4
25.	Limestone, fine-grained, gray	6
24.	Sandstone, light gray, coarse	25
23.	Shale, indurated, green	6
22.	Sandstone, fine-grained, light green	22
21.	Shale, light dove-colored, smooth	12
20.	Coal	4
19.	Sandstone, bluish gray, shaly, micaceous	6
18.	Shale, blue, smooth	18
17.	Shale, black, calcareous, bituminous, with coal and pyrite	9
16.	Limestone, nodular, green and gray	18
15.	Shale, smooth, calcareous	15
14.	Clay, impure, with coal	5
13.	Sandstone, drab and green	19
12.	Shale, brown, hard	4
11.	Sandstone, light gray, dark near top	54
10.	Clay, dove-colored	12
9.	Sandstone, drab and black	17
8.	Shale, blue, calcareous	23
7.	Sand, white and dark	67
6.	Shale, soft, dove-colored, sandy	10
5.	Sand	53
4.	Limestone, dove-colored and dark gray	134
3.	Sandstone, brown	52
2.	Chert, white	10
1.	Sandstone, various colors	5

ST. CHARLES COUNTY.

St. Charles is mainly underlain by the lower Carboniferous limestones, but an outlier of the coal measures occurs in the southeastern corner. The coal measures contain shale beds of workable thickness. The other formations contain thick shale beds in the adjoining St. Louis county, but not of sufficient purity to be of value, so that while they probably extend into this county, there value is very doubtful. At St. Charles is a thin coal bed that is overlain by 28 feet of dark shale.

ST. CLAIR COUNTY.

St. Clair county is largely underlain by the coal measures with the usual accompanying outlying basins, and by the lower Carboniferous limestone in the southeastern portion of the county. The former contains good shale beds. The latter contains a lean, calcareous shale, but it is usually too high in lime to be very valuable. At the Knowle coal stripping one and one-half miles southeast of Appleton City the following section occurs:

		Feet.
5.	Limestone, hard, dark, compact	1
4.	Shale, soft, yellow and drab	3
3.	Shale, black, fissile, brittle	2
2.	Coal, with parting	2
1.	Shale, gray (exposed)	1

At the Carroll shaft one and one-half miles west of Johnson City, 15 to 20 feet of fine drab shale occur over the seam of coal at a depth of 40 feet. At the Bell shaft two miles east of Osceola are 6 feet of shale overlying the coal at a depth of 15 feet. About four miles west of Osceola at the Johnson drift, formerly the Hoover slope, are:

		Feet.
5.	Soil, surface	2
4.	Sandstone	6
3.	Shale, bluish, pyritiferous	8
2.	Coal	2½
1.	Shale	4

ST. FRANCOIS COUNTY.

The limestones and sandstones of Cambrian and Ordovician age are the surface rocks over much of the county. Through them protrude hills of porphyry and granite. The limestones have frequently shaly layers which sometimes thicken to 4 feet and in a cut of the Mississippi River and Bonne Terre railroad between Big river and the Valle mines, there are 10 feet of shale. In the lead-mining camps of Bonne Terre and Flat River the limestone is especially shaly at or near the surface in the former camp and at a depth of 150 to 350 feet in the latter place. The shales are not valuable, as they are not only very thin, but are usually too calcareous to possess sufficient strength after burning.

STE. GENEVIEVE COUNTY.

Ste. Genevieve county has a belt of lower Carboniferous limestones along the Mississippi river, and Ordovician limestones and sandstones over most of the district. The former contain at least one thick bed of shale, which is exposed in the bank of south Gabouri creek. On the Sexaner land near Ste. Genevieve, on the Farmington

plank road a thick bed of shale occurs at the base of a hill on south Gabouri creek. A face of 20 feet is exposed that is overlain by soil and gravel. A sample gave the following results: Color gray to blue or yellow. Texture laminated, rather hard (2.0 to 2.5), and coarse-grained, with some sandy streaks. Taste, lean to sandy. Slacked slowly and imperfectly into flakes and granules one-fourth to one-half of an inch in size. Pyrite was not noticeable; some sandy streaks occurred; hydrochloric acid caused no effervescence. When ground to 20-mesh and mixed with 10.0 per cent of water it made a rather plastic to slightly lean paste that shrunk to 6.0 per cent in drying and 5.6 per cent when vitrified, giving a total shrinkage of 11.7 per cent. The average tensile strength of the dry mud was 117, and the maximum 148 pounds to the square inch. Incipient vitrification occurred at 1,600° F., complete at 1,700°, and viscous above 1,900°. It burned to a compact, tough, red body, when vitrified. It dried rapidly but required to be slowly heated to avoid cracking. It is suitable for terra cotta and paving-brick.

A chemical analysis gave the following results:

	Per cent.
Silica	59 97
Alumina	21.15
Combined water	5.71
Moisture	1.25
Iron sesquioxide	5.20
Lime	1 55
Magnesia	1 10
Alkalies	3.88
Total	99.81
Total fluxing impurities	11.77
Specific gravity	2.41

ST. LOUIS COUNTY.

The northeastern part of the county is covered by coal measures, while the southern and western portions are underlain by the limestones of the lower Carboniferous and earlier rocks. Shales occur principally at two different horizons (a) in the coal measures, in the eastern and northeastern portion, and (b) in the lower Carboniferous in the western portion, near Barrett.

There is a well defined shale bed in the coal measures that immediately overlies the fireclay seam that is so extensively worked at Cheltenham, while the latter usually rests on ferruginous sand stone. The shale bed is very variable in thickness and quality, as it

ranges from 5 to 70 feet in thickness and from a soft, plastic, grey to red shale to a hard, very arenaceous, lean valueless shale. Some of it is exceptionally well adapted for paving-brick, as at Propsect Hill, and it is used in small amounts at Cheltenham in admixture with fireclay by some of the sewerpipe factories. The prevailing trouble with this shale is that through contamination with carbonate of lime and iron it "bloats" or swells up into spongy, scoriaceous mass when vitrified. Only one development is known that is very thick which is at Prospect Hill, where there are 70 feet, but this thins out to less than 5 feet within a mile at the Baden water works.

Beginning at the north end of the county, this bed of shale shows in the bank of Watkins creek, at the crossing of the Columbia bottom road, where it is 8 to 10 feet thick. About two miles south of this point on what was formerly known as the Sattler lands, adjoining the Columbia bottom road, is the following section:

	Feet.
7. Clay, yellow (loess)	52
6. Gravel	5
5. Shale, soft, drab	7
4. Shale, hard and slaty	60
3. Coal	1
2. Fireclay	25
1. Sandstone	18

About one and one-half miles southwest of the Sattler land at Prospect Hill, the shale is from 50 to 70 feet thick, and is mainly above the level of the Columbia bottom road instead of being entirely below it. At this place, the lower portion of the bed is a soft, very plastic, gray to olive shale, while the upper portion is more arenaceous, and from olive to red in color, with a capping of gray sandstone that is 10 to 12 feet in thickness. A sample of the lower gray portion of the bed gave the following results: Color gray to olive, with yellow to brown iron-stainings. Texture finely lamellar, soft, and fine-grained. Taste, smooth and plastic. Slacked into coarse flakes and granules. Pyrite was not noticeable; acids caused no effervescence. When ground to 20-mesh and mixed with 20.0 per cent water it made a plastic paste that shrunk 5.3 per cent in air drying and 8.2 per cent in burning, giving a total shrinkage of 13.5 per cent. The air-dried mud had an average tensile strength of 177, with a maximum of 179 pounds to the square inch. Incipient vitrification occurred at 1,700° F., complete at 1,900°, and viscous above 2,100°. It burned to a compact, dense, very tough, red body. It is admirably adapted for paving-brick, terra cotta and roofing tile.

An analysis made by Chauvenet gave the following results:

	Per cent.
Silica	60.70
Alumina	18 20
Combined water	6.77
Iron sesquioxide	7.58
Lime	2.68
Magnesia	trace.
Alkalies	3.67
Total	99.62
Total fluxing impurities	13.93
Specific gravity	2.42

The general dip of this shale bed is to the northwest, and its maximum thickness is at Prospect Heights, where there are at least 70 feet, the greatest thickness known in the county.

About one mile south of Prospect hill in the excavation made for the new waterworks at Baden is the following section:

		Feet.
7.	Soil, black	2
6.	Sand	18
5.	Sand and pebbles	8
4.	Sandstone, gray	10
3.	Shale, yellow	2
1.	Limestone (St. Louis) exposed	32

In the cut of the Oak Hill railroad as it passes under the Morgan Ford road, at Oak Hill, the following section is exposed:

		Feet.
4.	Clay, yellow (loess)	20
3.	Shale, red	5
2.	Shale, olive green	10
1.	Limestone, fossiliferous	2

At the shaft of the Christy fireclay mine, one mile south of Oak Hill, are:

		Feet.
6.	Clay, yellow (loess)	34
5.	Gravel, drift	1½
4.	Shale (pipe-clay)	14
3.	Shale, green	5
2.	Shale, black	4½
1.	Fireclay	6

At the Tole and Thorpe fireclay mine, one and one-half miles northwest of the last, the following were met with in sinking the shaft:

		Feet.
9.	Clay, yellow (loess)	10
8.	Limestone	20
7.	Coal	1
6.	Fireclay, with bowlders	10
5.	Flint (limestone?), yellow	4½
4.	Fireclay	7
3.	Shale, blue	13
2.	Sandstone, black	4½
1.	Fireclay	13

At the Evens and Howard fireclay mine, at Cheltenham, the shale is about the same thickness as at the mine just described:

		Feet.
8.	Clay, yellow (loess)	15
7.	Gravel	1
6.	Shale (pipe-clay)	8
5.	Shale	14
4.	Sandstone	7
3.	Coal	1·6
2.	Fireclay (Cheltenham seam)	8
1.	Sandstone	8

The following section occurs at the Wrisberg fireclay mine, at Cheltenham, on the north side of the New Manchester road:

		Feet.
10.	Loess	20
9.	Limestone, fragments	3
8.	Clay, white and yellow, "fireclay" used for sewerpipe	4
7.	Clay, yellow and red	3
6.	Clay, gray to white	1½
5.	Shale, pipe-clay, reddish brown and greenish	12
4.	Sandstone	7
3.	Shale, slaty	¼
2.	Coal	¼
1.	Fireclay, sandy toward base	10

At the Laclede mine is the following section:

		Feet.
6.	Loess	25
5.	Shale, olive to gray to red	20
4.	Sandstone, cross-bedded and very shaly	7
3.	Fireclay	½
2.	Coal	½
1.	Fireclay	8

A sample of the sewerpipe clay, which consisted of the lower part of the loess clay with more or less of the shale gave the following results: Color white to highly yellow or brown. Texture shaly to compact and fine-grained. Taste, smooth. Slacked readily into one-thirtieth to one-thirteenth of an inch granules. Pyrite was not noticeable; gypsum was present as small white scales. When ground to 20-mesh and mixed with 21.5 per cent of water it made a very plastic paste that shrunk 7.7 per cent in drying and 7.5 per cent when vitrified, giving a total shrinkage of 15.2 per cent. The air-dried mud had an average tensile strength of 175 and a maximum of 217 pounds to the square inch. Incipient vitrification occurred at 1,800° F., complete at 1,950° and viscous above 2,150.° It dried easily without checking and burned to a dark red, tough body when vitrified. It is well adapted for sewer-pipe, terra cotta and press-brick.

A chemical analysis gave the following results:

	Per cent.
Silica	59.96
Alumina	15.76
Combined water	7.70
Moisture	4.00
Iron sesquioxide	7.72
Lime	0.60
Magnesia	0.93
Sulphur	0.29
Sulphuric acid	0.73
Alkalies	3.66
Total	101.34
Total fluxing impurities	13 92
Specific gravity	2.05

A sample of the shale No. 5 of the section was also taken, which gave the following results: Color mostly dark purple, with some green. Texture compact, hard, laminated and uniform. Taste, fat. Slacked rather rapidly, but not completely. Pyrite and gypsum were not visible. When crushed to 20-mesh and mixed with 20.0 per cent of water it made a plastic paste that shrunk 6.0 per cent on drying and 6.5 per cent when vitrified, giving a total shrinkage of 12.5 per cent. The dried mud had an average tensile strength of 107, and a maximum of 130 pounds to the square inch. Incipient vitrification took place at 1,800° F., complete at 2,000°, and viscous above 2,200°. It dried rapidly and burned to a dark red, strong body.

A chemical analysis gave the following results:

	Per cent.
Silica	54.57
Alumina	23.61
Combined water	6 67
Moisture	1.03
Iron sesquioxide	7.88
Lime	0.52
Alumina	1.48
Sulphur	0.03
Sulphuric acid	0.44
Alkalies	3.55
Total	98.82
Total fluxing impurities	13.90
Specific gravity	2.32

At the Jamieson pot-clay mine, at Bartold, two miles west of Cheltenham the following section occurs:

		Feet.
9.	Clay, yellow (loess)	11
8.	Pipe-clay, nearly white	12
7.	Clay, loose, with balls of pyrite	2
6.	Shale, red, soft	9
5.	Shale, blue to yellowish	2
4.	Coal	1½
3.	Fireclay	7
2.	Sandstone	2½
1.	Limestone, lower Carboniferous	1

Small local pockets or outliers of the coal measures occur at in the cuts of the St. Louis and San Francisco railroad at Selma (8.5 miles), Windsor Springs (13 miles) and Meramec Highlands (14 miles) where red shales are exposed for 200 feet or more, from 3 to 12 feet thick; also in the cuts of the Missouri Pacific railroad immediately north of these points, or from one-half to one mile distant.

In the lower Carboniferous one-half mile west of Barrett station on the Missouri Pacific railroad is an exposure of shale that is 20 feet thick. A sample of this shale gave the following results: Color olive to gray. Texture lameller, soft, coarse-grained and uniform. Taste rather lean. Slacked somewhat slowly into coarse granules. Pyrite was not noticeable. When crushed to 20-mesh and mixed with 22.0 per cent of water it made a plastic paste that shrunk 6.0 per cent on drying and 3.4 per cent when vitrified, giving a total shrinkage of 9.4 per cent. Incipient vitrification occured at 1,925°, complete at 1,950°, and viscous above 2,000°. It burned to a soft, white body that has but little strength though it can be rapidly dried and heated.

A chemical analysis gave the following results:

	Per cent.
Silica	49.69
Alumina	17 40
Combined water	13.37
Moisture	1.16
Iron sesquioxide	4.01
Lime	8.07
Magnesia	4.16
Alkalies	2.73
Total	100.59

The excessive amount of lime and magnesia makes it impracticable to use this clay as it is too weak unless vitrified, and it melts too suddenly to be safely vitrified. This shale dips east, and is exposed in a shaft at Barrett station, where it is about 36 feet thick. This same shale shows in the cuts of the St. Louis and San Francisco railroad, about one-half mile south of Barrett where it is badly intermixed with limestone, and is extremely calcareous in consequence.

SALINE COUNTY.

Saline county is occupied by the lower Carboniferous rocks in the eastern portion, and by the coal measures in the central and western portions. The former usually consist of limestones, but sometimes contain a thick shale bed. The latter comprise several shale layers which vary in thickness and extent. At Slater 20 feet of drab shale overlie the coal seam in the Copeland coal drift. Near Marshall, on the Calme land (Tp. 49 N., R. XXII W., Sec. 1, NE. qr.) there occur 10 feet of dark blue to brown shale under 8 feet of sandstone. This

shale also is found a short distance to the north. About one and one-half miles east of Sweet Springs, the following section occurs:

		Feet.
5.	Slope, tumbled masses of brown sandstone	20
4.	Shale, brown and white	36
3.	Hematite, concretionary	3
2.	Sandstone	½
1.	Chert and purple clay	½

SCHUYLER COUNTY.

Schuyler county is underlain by the coal measures which contain beds of shale, but no large streams exist, except the Chariton river, to expose sections. The only shales mentioned below are on this stream or its tributaries, as the heavy mantle of glacial drift that covers this county effectually hides the outcrops. Norwood mentions in his general section of the county, which was constructed from sections along the Chariton river, about 30 feet of sandy, calcareous shale. About six miles west of Glenwood, on Lick creek, several thin beds of shale occur, the largest of which is 6 feet thick, and is overlain by about 30 feet of yellow clay and gravel.

SCOTT COUNTY.

Scott county consists of a large bench, mesa or tableland that extends from the Mississippi river at Commerce to Oran and Caney Creek, on the St. Louis, Iron Mountain and Southern railroad about 12 miles west, and from one mile north of Morley, to three miles north of Kelso, or about 12 miles in a north and south direction. This tableland is of Tertiary age and is surrounded by lowlands. The Tertiary tableland contains a light-colored bed of shale along its western border, which is well shown near Oran, as subsequently mentioned, and probably the same is exposed near Benton, where it does not seem to be as thick. This shale probably underlies the entire plateau, but it is not likely to be uniform either in quality or thickness. Other shales exist, and valuable potters' clays are found in the neighborhood of Commerce and Benton.

About one mile east of Oran at the base of the hills that skirt the road to Morley, there is a bank of coarsely laminated, olive to gray shale that crops out very persistently for over two miles. Usually only 10 to 15 feet are exposed, but at one spot over 40 feet are in sight, with indications that the normal thickness is at least as great as this. The shale is rather lean and does not weather into a plastic clay. About two miles east of Benton, on the Benton and Commerce road as it enters the bottom, there is an outcrop of 8 to 10 feet of a soft, sandy, fat shale.

SHELBY COUNTY.

Shelby county is mainly underlain by limestones of the lower Carboniferous. A small basin of coal measures extends from Marion county on the southeast, while the western boundary touches the edge of the main coal basin of the state. There are local beds of shale in the pockets of coal measures in the southeastern portion that are of local importance in quality and thickness, and this is also true in the western part of the county. The thick shale bed that occurs at Hannibal, intercalated in the Carboniferous limestone is not likely to be reached in this county except through shafts, as the streams do not cut deep enough to expose it. Three-fourths of a mile south of the railroad station at Lakenan is the following section:

	Feet.
5. Clay	6
4. Shale, olive, lean, soft, thick-bedded, and slightly calcareous	2½
3. Shale, gray	5
2. Sandstone	1
1. Coal	1

The shale No. 3 was sampled and gave the following results: Color dark gray (dry), with some brown iron stains. Texture coarsely lamellar, hard (1.5 to 2.0), coarse-grained and uniform. Taste lean and gritty. Slacked readily and completely, partially into flakes, but mostly into granules one-fiftieth to one-tenth of an inch in size. Pyrite was not noticeable; it was not affected by acids. When crushed to 20-mesh and mixed with 16.5 per cent of water it made a soft plastic paste that shrunk 6.2 per cent in drying and 4.2 per cent when vitrified, giving a total shrinkage of 10.4 per cent. The air-dried mud had an average tensile strength of 144 and a maximum of 167 pounds to the square inch. Incipient vitrification occurred at 2,200° F., complete at 2,400° and viscous above 2,600.° It burned to a gray, compact, tough ware when vitrified and dried rather rapidly and heated without cracking.

A chemical analysis gave the following results:

	Per cent.
Silica	58.50
Alumina	30.50
Combined water	6.74
Moisture	0.40
Iron sesquioxide	2 34
Lime	1 20
Magnesia	0 51
Alkalies	0.30
Total	100.50
Total fluxing impurities	4.35
Specific gravity	2.41

Near Shelbina 15 feet of a dark gray, sandy, very lean, soft shale were found in a well at a depth of 60 feet.

SULLIVAN COUNTY.

The coal measures of this county contain several beds of shale, some of which are exposed in the banks of the streams and railroad cuts. Shafts will be necessary to reach the lower and best beds. At the location of the Henry mill, on Locust creek, Norwood gives the following section:

		Feet.
13.	Limestone, bluish drab	½
12.	Shale, green	4
11.	Limestone, rough, nodular	½
10.	Shale, olive	7
9.	Limestone, flag-like	½
8.	Shale, blue, with limestone nodules, light blue to green, or dark red in lower part	4
6.	Limestone, drab and light blue	1½
5.	Shale, blue, calcareous	1
4.	Limestone, shaly, dark blue	1½
3.	Shale	2
2	Limestone, shaly, blue	1½
1.	Shale, blue and dark	2

On the Sodder land (Tp. 63 N., R. XX W., Sec. 27, SW. qr.) two miles northwest of Milan there occur 18 feet of shale. At the Milan coal shaft are:

		Feet.
11.	Interval	44
10.	Clay, soft	3
9.	Limestone, blue	1
8.	Shale, light blue	16
7.	Sandstone, shaly	7
6.	Shale, light blue	17
5.	Coal	3¼
4.	Fireclay	2
3.	Limestone, gray	2
2.	Shale, blue	5
1,	Sandstone, yellow, micaceous	8

The shale bed No. 6 was sampled and gave the following results: Color drab, when dry. Texture coarsely lamellar, rather hard (2.0), uniform and fine-grained. Taste, rather fat. Slacked slowly but quite completely. Pyrite was abundant in minute seams and scales; cold hydrochloric acid caused effervescence and gave a yellow solution (carbonate of iron). When ground to 20-mesh and mixed with 24.0 per cent of water it made a very plastic paste that shrunk 6.5 per cent in drying and 2.6 per cent when vitrified, giving a total shrinkage of 9.1 per cent. The air-dried mud had an average tensile strength of 171, and a maximum of 183 pounds to the square inch. Incipient vitrification took place at 1,600° F., and complete at 1,800°. It burned to a

compact, tough, red, vitrified body, and dried rapidly and heated without cracking.

About one-fourth mile south of Milan is the following section:

		Feet.
8.	Limestone	9
7.	Interval, probably shale	5
6.	Coal, with shale and limerock	1¼
5.	Shale	8
4.	Limestone, yellow, decomposed, ferruginous	8
3.	Shale, olive	10
2.	Limestone	8
1.	Shale	4

The shale bed No. 3 was sampled and gave the following results: Color olive gray (dry), somewhat stained brown. Texture coarsely lamellar, soft (2.0), somewhat coarse-grained and uniform. Taste, lean to finely sandy. Slacked completely into granules one-fortieth to one-half of an inch in size. Pyrite was not noticeable, but mica was abundant as very fine flakes; cold hydrochloric acid caused free effervescence and gave a deep yellow colored solution (carbonate of iron). When ground to 20-mesh and mixed with 22.0 per cent of water it made a stiff, plastic paste that shrunk 7.8 per cent in drying and 3.3 per cent when vitrified, giving a total shrinkage of 11.1 per cent. The air-dried mud had an average tensile strength of 237, and a maximum of 246 pounds to the square inch. Incipient vitrification occurred at 1,700° F., complete at 1,900°, and viscous above 2,050°. It burned to a compact, tough, red to dark red body, and dried rapidly and heated without cracking. It is well adapted for terra cotta, paving-brick and sewerpipe.

VERNON COUNTY.

Vernon county contains numerous beds of shale. Broadhead gives the following section at Marmaton (Tp. 36 N., R. XXXI W., Sec. 9):

		Feet.
7.	Sandstone	40
6.	Shale, olive	25
5	Coal	1
4.	Limestone, pyritiferous	1
3.	Shale, and fireclay with seams of concretionary limestone and coal	7
2.	Coal	1
1.	Sandstone, ferruginous	6

About a mile east of White Oak mills is the following section:

		Feet.
9.	Sandstone	5
8.	Shale, drab, sandy	12
7.	Sandstone, thin-bedded	5
6.	Coal, weathered	1-6
5.	Shale, deep blue, with bituminous layers and thin coal	34
4.	Shale, black	2½
3.	Limestone, rough, sandy, pyritiferous	½
2.	Coal, and shale	½
1.	Fireclay	2

At Moundville is the following section:

		Feet.
11.	Soil and clay	6
10.	Sandstone fragments	1
9.	Shale, soft	5
8.	Limestone	1½
7.	Clay, red	5
6.	Shale, light-colored	17
5.	Coal	2½
4.	Clay	1
3.	Coal	1
2.	Clay	½
1.	Coal	4

Twenty feet of shale, sandy in part, overlie the coal seam at Moundville. At the Frank strip-pit two miles southwest of the same town are 8 feet of hard black shale over the coal, while 11 feet below this occur 30 feet of shale and clay. At Timbered Hill is a bed, 10 to 14 feet thick, overlying the coal that is mined at a depth of about 60 feet. About three miles south of Deerfield where the Lambert iron bridge crosses Drywood creek gorge, the following section occurs:

		Feet.
6.	Soil, sand and gravel	1
5.	Sandstone, coarse, micaceous, gray to yellow	4
4.	Shale, thin-bedded, sandy, yellow	7
3.	Shale, thin-bedded, yellow and blue	2
2.	Shale, thin-bedded, blue, with parting of iron stone, near bottom	12½
1.	Shale, thick-bedded, very sandy, gray	1

A sample taken from No. 2. gave the following results: Color olive gray to bluish black, with a few yellow to red iron stains. Texture lamellar, soft (2.0), rather fine-grained. Taste, lean and occasionally sandy. Slacked not at all. Pyrite was not noticeable; mica was present in small amounts; sand was present as streaks one-tenth to one-fourth of an inch thick, and occasionally as concretions 1 to 6 inches in diameter. When ground to 20-mesh and mixed with 17.0 per cent of water it made a stiff and rather plastic paste that shrunk 4.1 per cent in drying and 3.9 per cent when vitrified, giving a total shrinkage of 8.0 per cent. The air-dried mud had an average tensile strength of 87, and a maximum of 97 pounds to the square inch. Incipient vitrification took place at 1,800° F., and complete at 2,100°. It burned to a very tough, compact, dark red to brown body when vitrified, and heated rapidly and dried without cracking. It is suitable for paving brick, sewerpipe and press-brick:

An analysis gave the following results:

	Per cent.
Silica	58.90
Alumina	21 38
Combine water	8.69
Iron sesquioxide	7.09
Lime	0 57
Magnesia	1.66
Alkalies	1 52
Total	99 81

One-half mile below Benzfield ford on the Osage river there occurs the following section:

		Feet.
3.	Soil and river deposits	25
2.	Sandstone, grading into sandy shale	15
1.	Shale, black to blue, laminated	4

A sample of No. 2 gave the following results: Character, finely bedded, shaly sandstone, with shale partings one-tenth to one-twentieth of an inch thick, between the one tenth to one and one-half of an inch sandstone layers. Color of sandstone light yellow of the shale blue to black to brown, both decidedly iron-stained. Texture not uniform, the sandstone decidedly granular, and the shale finely lamellar. Taste, gritty and very lean. Slacked not at all. Pyrite was not noticeable; mica was present as thin scales one-tenth to one-twentieth of an inch in size. The shale bed No. 1 of the above section, was also sampled and gave the following results: Color black (carbonaceous) to very slightly brown. Texture irregularly laminated, soft, fine-grained and uniform. Taste, lean and finely gritty. Slacked slowly and imperfectly to thin scales and coarse powder. Pyrite was present in very minute seams about one-twentieth to one-fiftieth of an inch thick. When ground to 20-mesh and mixed with 17.0 per cent of water it made a lean paste that shrunk 5.0 per cent in drying and 1.4 per cent when vitrified, giving a total shrinkage of 6.4 per cent. The air-dried mud had an average tensile strength of 105, and a maximum of 120 pounds to the square inch. Incipient vitrification occurred at 1,600° F., complete at 1,800°, and viscous above 2,000°. It burned to a compact, strong, brown to red body when vitrified, but blistered; it heated rapidly and dried without cracking.

A chemical analysis gave the following results:

	Per cent.
Silica	55 20
Alumina	22.39
Combined water	* 8.38
Iron sesquioxide	6.56
Lime	2.64

Magnesia	1.87
Alkalies	3.54
Total	100.08
Total fluxing impurities	14.11
Specific gravity	2.41

At the Prewitt coal pit about one mile west of Walker there are 12 feet of soft shale, which on sampling gave the following results: Color dark gray to yellow and brown. Texture uniform, laminated, soft, and very fine-grained. Taste, rather smooth. Slacked slowly and imperfectly to coarse granules one-eight to one-half of an inch in size. Pyrite was present as very fine crystals one-fiftieth to one two-hundredth of an inch, freely scattered through the mass; siderite concretions sparingly present. When ground to 20-mesh and mixed with 25.0 per cent of water it made a very stiff plastic paste that shrunk 6.3 per cent in drying, and 5.7 per cent when vitrified, giving a total shrinkage of 12.0. The air-dried mud had an average tensile strength of 129, and a maximum of 148 pounds to the square inch. Incipient vitrification occurred at 1,500° F., complete at 1,700°, and viscous above 1,900°. It burned to a good red color, and heated rapidly and dried without cracking. It is suitable for terra cotta, sewerpipe and brick.

A chemical analysis gave:

	Per cent.
Silica	54.54
Alumina	23.26
Combined water	7.71
Iron sesquioxide	7.34
Lime	1.44
Magnesia	1.82
Alkalies	4:12
Total	100.23

WARREN COUNTY.

Warren county is underlain by the limestones of the lower Carboniferous in the northern portion, by a belt of Devonian in the central and by the Ordovician limestones and sandstones in the southern part. The Devonian usually consists of a thin bed of shale that is from 3 to 5 feet in thickness. The other formations are liable to carry beds of shale that may be of sufficient purity and size as to be valuable. Near Jonesburg (Tp. 47 N., R. IV W., Sec. 13) in the bank of a small branch are exposed 4 feet of shale that is probably of Devonian age.

WASHINGTON COUNTY.

The shales are not abundant. Those which are exposed are generally too calcareous to be of use, though some of them can doubtless be worked to advantage in absence of better material. On the St.

Louis, Iron Mountain and Southern railroad, at the crossing on Big river, east of Blackwell and within a few yards of the county line, is the following section:

		Feet.
5.	Limestone, shaly, buff	8
4.	Limestone, gray, heavily bedded	20
3.	Shale, blue, calcareous	9
2.	Limestone, blue, thinly bedded, with shale bands	6
1.	Shale, blue (exposed to track)	8

WEBSTER COUNTY.

Webster county is underlain by the lower Carboniferous in the southern portion, and by the Ordovician limestones and sandstones in the northern part. The former usually consist of limestones and sandstones, with at least one bed of shale that is of workable thickness, the "Hannibal." The latter contain no beds of workable thickness, so far as known. At the Marshfield shaft, about three and one-half miles southeast of the town, is the following section:

		Feet.
9.	Soil and clay	20
8.	Shale	4
7.	Limestone, yellow (Chouteau)	10
6.	Shale, blue (Hannibal)	64
5.	Sandstone	1½
4	Limestone, yellowish, with purple streaks	10
3.	Limestone, shaly	2
2.	Limestone, magnesian, with chert	9
1.	Sandstone	1½

About one mile south of the County poor-house, near Marshfield are:

		Feet.
5.	Sandstone (Hannibal)	10
4.	Shale, drab, soft	25
3.	Interval	8
2.	Sandstone, coarse, red	10
1.	Limestone, magnesian (exposed)	2

WRIGHT COUNTY.

This county is underlain by the Ordovician limestones and sandstones, except in the extreme southwestern portion, where there are small areas of the lower Carboniferous formation. No shales of workable thickness are at present known in the former and only mere remnants of a coarse, lean, sandy, olive-colored shale occur in the latter. The evidence gathered seems to indicate that these shale remnants are the equivalent of the Hannibal formation. The cuts of the Kansas City, Ft. Scott and Memphis railroad, near Mansfield and Cedar Gap, show from 5 to 10 feet of this olive, sandy shale, but it is usually so broken and intermixed with chert as to be of doubtful economic value.

The erosion that has occurred in this portion of the Ozark uplift has removed the shales that probably once existed. Local bodies or remnants may prove of great economic value in the future industrial development of paving brick, buff-brick and terra cotta, for which the Hannibal shale is often well adapted. A sample of this shale taken at Mansfield gave the following results: Color light olive to yellowish green (dry), with considerable brown iron staining. Texture very coarsely lamellar to massive, hard (2.0), rather coarse-grained and uniform. Taste, lean and very sandy. Slacked very slowly into flakes one-tenth to one-half of an inch in size. Pyrite was not noticeable, cold hydrochloric acid caused copious effervescence. When ground to 20-mesh and mixed with 18.5 per cent of water it made a slightly lean paste that shrunk 5.2 per cent on drying and 4.7 per cent when vitrified, giving a total shrinkage of 9.9 per cent. The air-dried mud had an average tensile strength of 120, and a maximum of 134 pounds to the square inch. Incipient vitrification occurred at 1,900° F., complete at 2,100°, and viscous above 2,200.° It burned to a brown to gray, compact, tough brick and dried rapidly and heated without cracking. It is suitable for sewerpipe, some grades of terra cotta and for paving-brick.

TERRA COTTA DECORATIONS OF UNION TRUST BUILDING—ST. LOUIS.

mass of clay by the designer or artist. The moulded ware is very carefully and slowly dried, when the pieces are thick, they are usually hollowed out to increase the safety in drying. The drying is usually done on open floors, without artificial heat, and is held back, where the thinner portions tend to dry quickly, by covering them with damp cloths. When the ware is perfectly dry it is either burned in a muffle-kiln which completely protects the ware from "flashing", or it is burned in an up- or down-draught kiln, after being carefully boxed in to keep off the flames. This care to protect the ware from the flames in burning is necessary to not only secure uniformity in color, but also to avoid the disfigurement that results from the ashes that are carried over by the draught and which more or less spots, streaks and clouds the color. In a muffle-kiln the ware is entirely enclosed within an interior chamber that perfectly protects the ware from coming in contact with the flames, and it is therefore the safest and most satisfactory method of burning terra cotta, though it is more expensive in construction, maintenance and fuel than an unmuffled kiln.

In the growing appreciation of high grade and artistic terra cotta and the demand for bold designs by the modern architect, the modeling room and the studio are becoming of greater importance in the terra cotta "atelier" than the clay preparing department, or the kiln yard. The elaborate cornices of some of the recent office buildings, the grand entrances of public buildings (see plate XXI) and the decorations of fine residences (see plate XXII) are making a greater demand on the modeler and artist than anyone in the factory. The enormous range in design and adaptation that a plastic clay permits is a fascinating field for originality and when the results are obtained in what has proved to be one of the most resistant of all things to the elements, it should inspire the ablest efforts of the architect and artist. The clay-worker should therefore do his part in securing the most thoroughly prepared, most uniformly tempered, and purest colored clays as a basis for the work of the artist, use the best designed kilns, and employ the most reliable fuel, to perpetuate his efforts in an unmarred form.

Winkle Terra Cotta Works. This company was started in 1883 by Joseph Winkle, its president, in a modest plant at Cheltenham in the western portion of St. Louis. The output has steadily grown and the factory has been enlarged until now it is a large plant with a three-story brick building 50 × 250 feet, six muffle kilns and a capital of $40,000. The clays used are the shales, fireclays and loess found around Cheltenham, and an excellent buff clay from Glencoe, St. Louis county. From a local business in ornamental terra cotta a large trade

has been built up that extends over the entire county. The character of the ware also continues to improve and the plant is now turning out some of the most artistic as well as the boldest designs in terra cotta that this country has ever produced. About 3,000 tons of clay are used per annum and the value of the terra cotta product now exceeds $75,000 a year.

St. Louis Terra Cotta Co. This company built a small plant at Cheltenham in 1894, that adjoins the large Winkle terra cotta works of which it is an off-shoot. It is completely equipped with a 80 H. P. boiler and engine, dry-pan, revolving screen, pug-mill, wad mill, and drying floor, and is provided with two muffled kilns. On account of internal dissensions, very little work has been accomplished, though some very beautiful designs has been produced.

Kansas City Terra Cotta Lumber Co. This company attempted to manufacture porous hollow-ware, by the copious introduction of sawdust into the clay. The latter burning out, leaves a highly porous body. The market was too limited for this class of goods so its manufacture was abandoned several years ago. Since that time the company has been making building brick.

Statistics of Terra Cotta Works.

Name.	Location....	County.....	Capital.....	Began......	Engine.....	No. of boilers	Kilns........	Size of kiln..	Value of product, 1891..
Winkle T. C. Co.	Chelt'm..	St. Louis	$40,000	1883	1	1	6 muffle....	10 to 15 feet	$60,000
K. C. T. C. L. Co.	Kansas C.	Jackson	75,000	1886	1-125	3	4 circ. D.D / 5 clamp..	60 tons.....	2,125
St. L. T. C Co...	Chelt'm..	St. Louis	20,000	1894	1	1	2 muffle....	200,000 each	
Totals........	....	....	$135,000	....	.....	5	17	....	$62,125

ROOFING TILE INDUSTRY.

The clays and shales suitable for roofing tile should safely vitrify to a close, dense, strong body, give an attractive color, and dry readily without excessive shrinking. Coarse to moderate-grained shales that easily vitrify are generally most suitable for this purpose. The primary essential of the clay is an attractive color, as roofing is such a prominent object in the landscape, and the color most suitable for giving a pleasing and not too sharp a contrast to either the blue sky or a green background are the various shades of red. Dark colors are also used to some extent, which are obtained by artificially coloring the tiles with glazes or enamels, but they tend to give a gloomy effect to the

TERRA COTTA AND BUFF BRICK IN DOMESTIC ARCHITECTURE.

building. In this part of the country with the long severe winters, it is very essential that the tiles be vitrified, or "hard," in order to resist the severe action of the frost. In central and southern Europe where the winters are not severe, and in the oriental countries, tile roofing is very largely used as it is extremely popular on account of its durability, beautiful effect, and freedom from the annoyances of painting, corrosion, and constant repairs. On account of the winters there being so moderate, the tiles are generally "soft," or are not hard-burned, which makes it very much easier for the tile-maker in not being compelled to burn to vitrification, which latter causes a heavy loss from warping, cracking brittleness and excessive shrinkage; but soft tile in our severe climate is liable to go to pieces from the disintegrating action of the frost, should a cold snap quickly follow a heavy rain or sleet storm. While a hard tile does not absorb more than one to three per cent of moisture, when soaked for 24 hours, the soft tile takes up from ten to twenty per cent which makes them very susceptible to disintegration, if frozen when containing this amount of water. The much greater difficulty of manufacturing hard tile as compared with soft tile and the necessity of only producing hard tile for a permanent, reliable roof has delayed their introduction into this country, as they have only been used to any appreciable extent within the last fifteen years. But in the demand on the architects for a finer class of buildings, an effort has been made to improve the beauty and attractiveness of roofs, as well as their durability and this has resulted in the extensive use of tiles. The ability to get any shape or color and the great variety of design that is possible with clay enables the architect to secure with tile a shadow effect to obtain a harmony in attractive, unfading colors and to relieve the roofs of the monotony given by the usual roofing materials. Well made tile has the additional advantage of being absolutely free from decay, rust, fading buckling, expansion fractures, and other vital defects of the common roofing materials. It makes a roof that is cool in summer, and warm in winter. It is perfectly fire-proof and frost-proof, if hard burned, while it can be readily repaired in case of breakage. Tile effects are shown in the accompanying plate XXIII. The largest demand for roofing tile in the United States is in the east, where it is becoming to be very extensively used in the better class of buildings. There are four tileries in successful operation east of the Alleghany mountains. A demand for roofing tile has recently sprung up in the West, where it is rapidly becoming popular and in consequence there are now six tileries in the Mississippi valley of which the one at Akron, Ohio, is the largest in the country.

The first effort at tile-making in Missouri was made by the Mitchell Clay Co. of St. Louis which, about 25 years ago, attempted to make French roofing-tile at the plant at Cheltenham. After about five years of hard work, with disastrous results, it was finally abandoned although some of the tile can still be seen on some of the neighboring buildings.

No further effort at tile-making was made, after this failure, until recently when the Standard Tile Co. erected a plant at Prospect Hill, in the northern part of St. Louis. This company has a capital of $50,000 and is manufacturing under recent patents that are a great advance over the old continental method. The clay used is a very superior shale that readily vitrifies and which occurs in the immediate vicinity. It makes a tile of a bright red, attractive color, and great strength. The capacity of the plant is 5,000 squares a year. The tile are burned in down-draught kilns, of which there are two at present in use and two more under construction.

SEWERPIPE INDUSTRY.

Clays Employed. The manufacture of glazed sewerpipe requires a clay that can be burned to a hard, dense body, to give it strength. It should also contain free silica to decompose the salt in order to give it an impervious glazed surface. If the clay vitrifies as a paving-brick clay, it is especially desirable. As the trade prefers a dark-colored pipe the clay should contain abundance of iron in order to burn to the proper color. Hence the shales are naturally best adapted for this purpose, as they usually have an excess of silica, an abundance of iron, are readily burned to a dense, strong body that vitrifies without salting. The demands of the trade, however, require a bright glossy surface, so that the shale pipes are always salted. Fireclays, especially if impure, are largely used for sewerpipe, for while they take more heat in burning and do not usually make as strong a pipe as shale they generally contain an excess of silica, and hence can be salt-glazed while there is a much smaller loss from wilting or yielding from over-heating in burning, on account of their more fire resistant nature. As they usually make a light colored pipe, which sell less readily than the dark, some surface or other ferruginious clay is usually mixed to darken them. The more impure the fireclay the less heat is required to produce a strong dense body, and the darker is the resulting pipe.

It is very desirable that the shrinkage of a sewerpipe clay be uniform and as small as possible, as the least irregularity in the shape of a pipe greatly affects its market value, while the less the shrinkage, the less the risk of distortion or cracking in drying and burning. If the shrinkage is excessive, or the clay is difficult to dry or burn without

ROOFING TILE AND BUFF BRICK IN DOMESTIC ARCHITECTURE.

cracking grog is often added, which usually consists of finely pulverized bats, culls, and other damaged pipe. The use of grog is very undesirable, if it can be avoided, as it rapidly cuts the dies of the press, necessitating a more frequent renewal, while it increases the difficulty of making a regular, smooth surface. As sewerpipe is made by the stiff-mud process it demands a plastic clay, and the more plastic the better, provided the shrinkage and consequent danger of checking in drying and burning is not too great. Lean or very sandy clays cannot therefore be used, as they have not the requisite strength, which also debars the flint clays, though the infusibility of the latter makes them commercially prohibitory.

Manufacture of Sewerpipe. In the manufacture of sewerpipe, the clay or shale is usually ground in a dry-pan, then screened through a 7- to 12-mesh screen, and mixed with water to a stiff paste in wet-pans or chasers. The thorough mixing and control of the clays in tempering that can be secured in a wet-pan, is what determines their use for sewerpipe, and generally for most classes of hollow goods. When fireclays, potters' clays or surface clays are used, the expense of crushing in a dry-pan is done way with, and the entire crushing and tempering is done in a wet-pan. In hollow goods the tempering in a wet-pan is sometimes replaced by a pug-mill, on account of the less cost of the plant and greater capacity, but the product cannot be as well controlled as in a wet-pan. In making sewerpipe the tempered clay is raised by elevators to the top of a building that is usually three stories high, where it is fed into the clay cylinders of a vertical steam press. This pipe press consists of a steam cylinder that is from 40 to 48 inches in diameter, 3 to 5 feet stroke and below it is a clay cylinder into which the clay is fed, that is 16 to 22 inches in diameter. When the clay cylinder or pot is filled with clay, a piston or plunger is slowly forced down on the clay, by the steam cylinder above which forces the clay out of the bottom through a hollow die as a continuous pipe of stiff mud. The pipe is cut so as to give, after burning, the standard length of 2 or 2½ feet. After trimming the edges, the pipe is removed to the drying floor, where it requires to be very slowly and carefully dried to prevent cracking. Special shapes as traps, sockets, elbows and trees are made by hand in moulds of plaster of Paris, and dried with special slowness so as not to open the seam at the joints. In the summer season the pipes are usually dried by having the windows of the drying floor more or less open, but in winter it is necessary to use a gentle steam heat to hasten the process. The smaller sizes of pipes are from three to twelve inches in diameter, are easily dried on account of their

thinness, but the larger sizes, from 15 to 30 inches in diameter, must be dried very slowly to prevent cracking.

The factory building is usually three stories high with the press situated near the center and all three floors are used for drying by carrying the pipe on cars and using the platform elevators to convey the pipes from one floor to another. When perfectly dry the pipes are slid down on slides to the kilns.

The type of kiln used is the round, down-draught or bee-hive, which for this purpose is made from 18 to 30 feet in diameter, the usual sizes being from 20 to 25 feet. There are usually ten kilns to a press, as it takes about ten days to turn a kiln. The pipes are set vertically from 9 to 15 feet high, after leveling up the floor with slugs or wads of clay, and the smaller pipes are set concentrical within the larger pipes. The setting takes a crew of five men from three-fourths to one day, who usually both set and empty the kiln. On account of the thinness of the pipes the water-smoking takes only one to two days, while the firing takes from three to five days, depending on the thickness of the pipes. When the pipes have reached the highest heat and have about finished settling, they are glazed or salted by adding a small amount of salt at each firehole. Usually the fires are salted twice and from 150 to 300 pounds of salt are used. The salt is volatized by the heat, and the salt vapor, coming in contact with the clay which is usually at an orange heat, is decomposed, and forms an insoluble double silicate of soda and alumina or a glass on the surface. After the salting the kilns are closed and allowed to slowly cool, taking from three to five days. When nearly cold, the ricket or door is gradually opened, so as not to cause the pipes to crack by too sudden cooling. The "settle" or shrinkage usually amounts to 5 to 7 inches in the center of the kiln. Emptying the kiln is rapidly and easily accomplished when cold in one-half to three-quarters of a day, in doing which the pipes are first carefully sorted into first-class, second-class and culls. First-class pipes must be perfect in shape, free from checks or cracks and uniform in color. Any defects as blisters, iron spots, imperfect glazing, irregularities in shape, or want of uniformity in color, cause the pipes to be rated as "seconds" which bring a much lower price. The trade is very exacting, and demand a superior article for the No. 1 grade. If the heat is raised too high, there is a heavy loss from wilting, sagging, or yielding of the pipes, while if the heat is too low, the pipes do not decompose the salt vapor and do not become glazed. The badly misshapen, cracked and broken pipe are broken up for grog. The burning of sewerpipe is comparatively easy, as on account of the open character of the material there is no trouble in getting a good draught or an

A CHARACTERISTIC SEWER-PIPE PLANT.

equal distribution of the heat. Great care must be exercised if shale is employed, to avoid overheating and a consequent heavy loss from distortion. The interior of a sewerpipe kiln becomes encrusted with a thick glaze from the repeated effect of the salt vapors. One of the largest sewerpipe kilns in the United States is located at Cheltenham or west St. Louis, and is 30 feet in inside diameter.

As the heavy demand for pipes is in the spring and summer, during construction of sewers and railroads, it is necessary to have a large yard to store the output of the winter months, when there is little or no demand. The large number of sizes made, from 3 to 30 inches in diameter, as well as the numerous special shapes, requires the maintaining of large stocks. The standard length of sewerpipe is 2 feet, but special shapes and sizes can be made if called for. The largest sizes made are usually 24 to at most 30 inches, as when the sizes exceed this, the sewers can usually be built more cheaply with brick.

There are five companies engaged in the manufacture of sewerpipe in Missouri, that represent an invested capital of $1,025,000, and a product of about $1,110,000 worth of ware a year. Three of the concerns are located in St. Louis, each of which has a large double plant, while two are located in the western part of the state to save the freight in catering to the growing far western trade.

ST. LOUIS.

Blackmer and Post. This is the largest plant in Missouri that is exclusively devoted to the manufacture of sewerpipe. At present the entire plant is concentrated at Reber Place station, on the Oak Hill railroad, where the first plant was erected in 1887. The company formerly had a one-machine factory at Ewing avenue, in the Mill creek valley, that was built in 1880 and another on Papan street; but the growing demands for the railroad crowded out these sites, which resulted in the final rebuilding of both plants at Reber place, in 1893. Both are shown with their large pipe yard in plate XXIV. The older of the Reber place factories consists of a three-story, substantial brick building that contains one Barber steam press of 44 inches and eleven bee-hive, down-draught kilns, 20 feet in diameter. The pipes are made from a mixture of two-thirds pipe-clay and one-third common yellow or brick clay, which comes from a pit about one mile west near the poor house. Formerly considerable clay was shipped in from Washington and Glencoe, on the Missouri Pacific railroad, but this has been discontinued on account of the expense. The clay is crushed in a 9-foot dry-pan, screened over a riddle 2 by 16 feet that is set at an angle of 30 degrees, and tempered to a stiff mud in two, 7-foot wet-pans.

The pipes are dried on three drying floors in the usual manner by steam pipes fed from exhaust steam from the boilers. The factory is run by an engine that is rated at 150 H. P., and supplied with steam by three 4 by 20 feet boilers. It takes seven to eight days to cool off, or about 11 days to turn a kiln. About 300 pounds of salt are required for each kiln to give the sewerpipes the waterproof glaze. The new factory is immediately north of the old one, and is a four-story brick building, 100 by 250 feet. It has ten bee-hive kilns 25 feet in diameter.

The firm ships sewerpipe from Winnipeg, on the north, to Mexico on the south; and from the Pacific coast on the west, to Cincinnati on the east, where the competition of the Akron (Ohio) pipe works becomes too keen. Pipes are manufactured from 3 to 30 inches in diameter and in length of 24 to 30 inches.

The clays are hauled by wagon from a pit that is about 1,000 feet south of the poor house and about 2,250 tons a month are used.

The following is a section of the pit:

	Feet.
6. Loess or yellow brick clay	20
5. Clay and gravel	2
4. Sandstone, yellow, thin-bedded	2
3. Pipe clay	12
2. Sandstone	8
1. Fireclay	4

A view of the pit looking west is given on plate XXV. It shows the stripping of the loess with its badly furrowed surface (from recent rains), above the sandstone, and the digging of the pipe clay by pick and shovel below the sandstone. The pipe clay is an imperfectly bedded, highly impure, fat clay, though essentially a gray clay it is heavily stained yellow to red by iron. The overlying loess or brick clay is added to darken the color of the pipe.

Evens and Howard. This large establishment, of which a photograph is shown in plate XV, makes sewerpipe in addition to a large quantity of firebrick. The sewerpipe is made from two-thirds fireclay and one-third loess or yellow brick clay, with a small amount of grog made from the bats and fragments of damaged pipes. The clay and grog is crushed in a dry-pan, and then screened on a 10-mesh inclined screen that is 12 feet long by 2 feet wide, and tempered to a stiff paste in four wet-pans. The two 40-inch steam presses and the crushing machinery are located side by side in a large four-story building, in which all the floors are used for drying. There are 22 round, down-draught kilns that vary from 25 to 35 feet in diameter. Pipes are made from 3 to 24 inches in diameter which are marketed all over the country. About 30,000 tons of clay are used each year.

A LARGE ST. LOUIS CLAY PIT.

Laclede Fire Brick Co. This very large plant is a heavy manufacturer of sewerpipe in addition to firebrick, fireproofing, gas retorts and other clay wares. There are two adjoining factories, each of which is equipped with a 40-inch steam press that is capable of handling 50 tons of clay each shift of ten hours. For the sewerpipe a mixture of one-third fireclay, one-third shale (that occurs over the fireclay) and one-third loess or yellow brick clay, is used. Each factory is equipped with two dry-pans, and a 10-mesh screenthat is 30 inches wide and 24 feet long that sets at an angle of about 35 degrees. The ground clay is tempered to a stiff mud in a pair of wet-pans. There are 21 round down-draught kilns that vary from 20 to 30 feet in diameter.

KANSAS CITY.

Kansas City Sewer Pipe Works is located on the Missouri river flood-plain, about four miles east of the Kansas City Union station. It is equipped with a 44-inch steam-press that has a 20-inch clay cylinder and there are 12 round down-draught kilns that range from 20 to 30 feet in diameter. All the clay is shipped to the factory from a distance, and a mixture is made that consists of one-third loess or yellow brick clay from Independence, Jackson county, one-third blue shale from Montserrat, Johnson county, and one-third gray shale from Bloomington, Buchanan county; also shale from Deepwater, Henry county. The clay is crushed in a 9-foot dry-pan, screened over a fixed screen, 2½ by 15 feet, pitched at an angle of 40 degrees. It is tempered to a stiff mud in three wet-pans. The plant is run by a 150 H. P. engine, and two 5 by 20 feet boilers. There are three drying floor and the exhaust steam is used by day, and the steam by night for drying.

DEEPWATER.

Dickey Sewer Pipe Works. The equipment consists of a 42-inch steam press that has a 22-inch clay cylinder, and 8 down-draught, beehive kilns from 20 to 30 feet in diameter. A shale is used that is obtained from a bank immediately back of the building and about 80 tons are used daily. The clay is crushed in an 8-foot dry-pan, screened through a 3-16 inch screen that is 2½ by 18 feet and pitched at an angle of 40 degrees. It is tempered to a stiff mud in two 8-foot wet-pans. The plant is operated by a 80 H. P. engine and two 5 by 20 feet boilers. The product is shipped to Kansas City, the southwest and the Far West.

Statistics of the Sewer Pipe Industry.

Name.	Location.	Capital	Began	Machine—Plunger....	H.P. engine	Boilers.	Kilns..... ..	Size of kiln..	Value of product, 1891...
Blackmer & Post	St. Louis.....	$300,000	1880	1	.....	..	10 circ. D. D	20 ft. D.....	$200,000
Blackmer & Post.	Reber Place.		1887	1	1-100	3	11 circ. D. D	20 ft. D....	
Evens & Howard.	Cheltenham.	250,000	1855	2	....	..	30 circ. D. D	20 to 35 ft D	210,000
Laclede F. B. Co.	Cheltenham.	325,000	1855	2	2 100	3	18 circ. D. D 6 sq D. D..	21 to 30 ft. D 18 by 27 ft.	450,000
Dickey C Mfg. Co	Deepwater..	50,000	1886	1	1-80	2	8 circ. D. D	20 to 30 ft. D	150,000
Kansas C. S. P. Co.	Kansas City.	100,000	1885	1	1-85	2	12 circ. D. D	20 to 30 ft. D	100,000
Totals..	... .	$1,025,000	...	8	.....	..	95	....	1,110,000

DRAINTILE INDUSTRY.

Clays Employed. The clays suitable for draintile, or the porous earthenware pipe that is used for draining wet farm lands, are similar to those that are used for building brick, or the loess, glacial, residual and surface clays. The shales are also well adapted for this purpose, and the fireclays, especially if impure, are used. In fact any plastic clay that can be dried and burned to a porous body of reasonable strength answers for this purpose. The gumbo clays are about the only class that can be generally condemned, from the inability to dry and burn them without going to pieces.

The requirements for draintile are a soft, porous, non-vitrified body, in which great strength is desirable, though not absolutely essential. The ware must be so porous as to readily permit the penetration of water, so that it can readily drain the water-soaked land in which it is laid. Color is of no real importance, though a light red color is a favorite one as indicating both strength and a porous body in most clays. The use of draintile in Missouri is steadily growing, and with great advantage in the prairie county of the northern half of the state where the heavy clay soils remain water soaked for a long time after a wet spring, unless drained. Thorough drainage by tiles has accomplished much in benefiting the prairie and low bottoms of Illinois, Indiana and Ohio where they are very extensively used.

The cost of erecting a draintile plant is very moderate, as a horse-power outfit with one small kiln can be built for less than $1,000, and a steam outfit can be equipped for quite a large output for $5,000 to $10,000. As clays that answer for this purpose occur throughout the northern half of the state, and as a very moderate outlay of capital

suffices for a large farming community, draintile plants should spring up in every important farming district, at least in the prairie or bottom lands. They can be operated during the midsummer period of dullness and again in the late fall, when there is little to be done. In selecting a site for a tile yard the clay should be neither too lean or too sandy as it then makes a weak, tender tile; nor too strong or plastic when it cracks or checks in drying and burning. If the clay seems suitable in having a moderate plasticity and the dried mud has considerable strength, it is well to test it on a large scale, before erecting a plant, to positively ascertain whether it can be readily dried and burned without checking, a very important matter that can only be definitely determined by such a test. Some clays that cannot be used fresh from the bank, because of the trouble in drying and heating, often become tractable after weathering over winter.

The clay is perfectly tempered by soaking in pits for 24 hours, similar to making hand-made brick. The tempering can also be satisfactorily performed by pug-mills or wet-pans. The tempered clay.after being mixed with water to a rather stiff mud, is fed to the tile machine which is of the continuous auger or plunger type. At small plants the tile machine is frequently run by horsepower, but at the larger plants steam power is usually used and the Penfield, Frey-Sheckler, Wallace and other makes are generally employed. Different sized dies are attached to the machines, according to the size of pipe desired, the smallest size being 2 inches, while the largest size rarely exceeds 12 inches. The pipe is cut by hand power or automatically in lengths from 1 to 2 feet and is made without a lip, so that they make a simple butt joint when laid. The moulded pipes are made from a mud that is sufficiently stiff to bear handling without injury, and are usually dried in open sheds. When the clay does not stand rapid drying in an open shed without checking, canvas or board sidings are used to shut off the wind and sun thus retarding the drying. When perfectly dry the tiles are burned in kilns that are usually of the round down-draught type. They are placed within one another, and set vertically, and wads of clay used to level up and keep them in line.

The burning is usually very easy as the ware is so thin that it is readily water-smoked, taking from 12 to 36 hours, according to the clay, while the open character of the ware gives a ready passage for the heat without danger of choking from soot. After the water-smoking period, the fire is urged for 24 to 48 hours longer, and the kiln is closed and allowed to cool. A bright red heat usually suffices with most clays, to give sufficient strength without closing or choking up the pores of the ware. If too much heat is employed, the pipe is not only liable to

Statistics of Draintile Industry.

Number	Name.	Town.	County.	Began	Machine.	Capacity.	Engine, H. P.	Boilers, H. P.	No. of kilns	Method of drying.	Tile product in 1891	Value of produc in 1891
1	Gill and Aldrich	Golden City	Barton	...	Mascot (Auger)	...	10	...	1	Air	25,000	$450
2	Lamar Pottery	Lamar	Barton	1869	Eureka	5,000', 8" tile	...	...	2	Air	20,000	800
3	Miller and Sons	Butler	Bates	1878	...	...	...		1	...	58,000	1,200
4	Rich Hill Vitrified Brick and Tile Co.	Rich Hill	Bates	1892	Kell's Anger	2,500 brick	80	40	1	Air	...	500
5	McCubbin, W. M	Braymer	Caldwell	1892	Eureka	...	...	...	3	Air	None.	None
6	Clements, Chas	Norborne	Carroll	1889	...	...	25	80	2	Air and steam.	221,000	8,800
7	Crouch and Harding	Carrollton	Carroll	1888	Centennial	80,000 brick	25	25	2	Air	...	8,000
8	Brunswick Brick and Tile Co	Brunswick	Chariton	1886	Boyd Dry-press	20,000 brick	30	80	5	Air	...	2,000
9	Muckey, H., and Co	Triplett	Chariton	1886	...	40,000 brick	20	...	1	Air	...	1,000
10	Billings Brick, Tile & Terra Cotta Wks	Billings	Christian	1890	Penfield No. 4	...	10	10	8	Furnace	...	1,000
11	Darlington Tile and Brick Works	Darlington	Gentry	1885	Adrian No. 3	8,000', 8" tile	20	25	1	Air	...	2,000
12	Hipp, F. G	Darlington	Gentry	1885	McKinsey	20,000 brick	25	...	2	Air	20,000	800
13	Powell, Jacob	Independence.	Jackson	1887	...	...	...	...	2	...	...	2,000
14	Howell, R	Dallas	Jackson	1887	Little Giant	2,500', 8" tile	10	...	1	Air	...	1,000
15	Howell, G. W	Dodson	Jackson	...	...	...	...	...	...	...	...	500
16	Montserrat Tile Co	Montserrat	Johnson	1887	Chandler & Taylor	8,000', 8" tile	...	...	1	Air	165,000	1,860
17	Campbell and Ligon	Higginsville	Lafayette	1891	Nolan & Madden	12,000', 8" tile	24	24	1	Air	50,000	825
18	Shafernolte, F	Higginsville	Lafayette	1882	Penfield	4,000', 8" tile	...	...	4	Air	125,000	1,875
19	Niemann, Gottlieb	Alma	Lafayette	1889	Penfield	5,000', 8" tile	...	..	1	Air	160,000	2,400
20	Sayling and Davis	Odessa	Lafayette	...	...	...	...	...	1	...	...	1,500

21	Kriemsiek, H	Corder	Lafayette	1886	Phoenix		...	...	2		225,000	3,375
22	Winfield Tile Works	Winfield	Lincoln	1888	Brewster	10,000', 3" tile	20	20	1	Air	128,000	2,557
23	King Tile and Brick Works	Brookfield	Linn	1892	Frey-Sheckler		25	....	1	Air		1,000
24	Hummel, J. M	Florence	Morgan	1859	Chandler & Taylor	3,000 brick	...	....	1	Steam		100
25	Bollinger and Taylor	Burlington Jc.	Nodaway	1884	Penfield	5,000 brick	....	...	3	Air	60,000	900
26	Kinney, J. A	Pickering	Nodaway				....	....	2			....
27	Roberts, Norton	Quitman	Nodaway	1889	Hoosier	3,000 brick	....	....	1	Air	63,000	945
28	Wallace and Bro	Clermont	Nodaway	1892			....	...	1			500
29	Dunnegan Pottery	Bolivar	Polk	1886			....	...	1			300
39	Cort, A. B.	Mt. Leonard	Saline	1890	Frey-Sheckler	8,000 brick	20	23	1	Air	70,000	1,050
31	Pauls, C.	Mt. Leonard	Saline	1892			...	...	1			1,500
32	Crouch, H	Arrow Rock,	Saline	....			....	...	1			500
33	Elder, Biglow and Co	Gilliam	Saline	1886	Nolan & Madden	16,000 brick	12	12	1	Air	300,000	4,800
34	Elder, Biglow and Co	Slater	Saline	1892		12,000 brick	25	30	1	Air		1,500
35	Gilmore	Marshall	Saline				...	....	1			500
36	Vaughn and Smith	Shackelford,	Saline	....			....	....	1			1,500
37	Dexter Pottery	Dexter	Stoddard	1891	Eureka	4,000', 4" tile	...	...	1	Air		300
37	Totals			....			....	....	54			$48,287

wilt or become distorted or misshapen, but the shrinkage becomes excessive, which greatly endangers the leaning and throwing of the pipe, while the body becomes so close and dense as to lose its valuable porous, open character. Up-draught kilns can be employed, but there is usually a heavy loss of over-burned, misshapen tiles at the bottom of the kiln, while in the upper portion the ware is too soft and insufficiently burned. In the down-draught type of kilns it is easy to burn the tile uniformly from the top to the bottom of the kiln, or at all events there is but a small percentage of underburned tile at the bottom.

The manufacture of draintile is often carried on at brick works, in connection with the brick departments, as the same clay can be used for both purposes and by changing dies, the same machinery can be employed. The table of draintile works in Missouri gives the following summary:

Number of works	37
Number of kilns	54
Value of product for 1891	$48,287
Estimated capital	$58,000

While the value of the product has not yet reached the figure of Illinois, Indiana and Ohio, there has been a large development of the industry in Missouri within the past ten years, which is likely to grow considerably as the benefits of subsoil drainage become better known, and as the bottom lands and wet prairies are reclaimed.

FLOWER-POT INDUSTRY.

The manufacture of flower pots, as carried on in this state, is usually a distinct industry in itself. As it is a class of ware that is cheap and does not bear long transportation, while the demand is limited, it is always a local business, and the plants are very small in consequence.

The clays employed for this purpose are the same as for brick and draintile, when a red flower pot is desired, and potters' clays if a cream or buff color is wanted. The process of tempering, drying and burning is identical with that used in the manufacture of draintile. The moulding is done either by turning on a potters' wheel, in plaster of Paris, or in presses. The plain pots are moulded by hand in small yards and pressed in large yards, while plaster of Paris moulds are used for ornamental ware.

As the ware should be open and porous it is not burned very hard, though it is occasionally slipped or lead glazed on the exterior to improve the appearance. In the St. Louis district a mixture is usually employed that consists of two-thirds loess clay and one-third plastic

fireclay (Cheltenham) the latter being added to render the mass more plastic. The pots are usually burned in down-draught kilns of small size, so as not to put too much weight on the lower courses.

A summary of the following table shows that this industry consists of:

Number of plants	7
Number of kilns	8
Estimated capital	$30,000.00
Value of output in 1891	$30,700.00

Statistics of Flower Pot Industry.

Name.	Locality.	Began.	Machines.		Kilns.	Product, 1891.	Value, 1891.
			Presses.	Wheels.			
Chas. Weyrichs	Boonville	1867	1	2	1	....	$3,000
Missouri P. & Mfg. Co.	Kansas City.	1888	3	4	1	....	18,000
Aug. Obermeyer	St. Louis.	1889	1	1	1	26,000	1,200
Jno. Muttig	"	1874	1	2	2	....	5,500
Martin Pauls	"	1868	....	2	1	....	600
August Seeber.	"	1868	1	....	1	80,000	400
C. A. Schwartzkopf	"	1883	2	2	1	150,000	2,000
Totals	....	....	....	....	8	....	$30,700

CHAPTER XIV.

PAVING-BRICK CLAYS AND INDUSTRY.

HISTORICAL SKETCH.

The paving-brick industry is the youngest of the special applications of clay in the United States. It has developed within the last fifteen years, though established in Holland for more than a century. The use of brick for street-paving in the United States dates as far back as 25 years ago (1870), when an experimental block was laid in the town of Charleston, West Virginia. As this experiment proved a success Charleston paved several blocks with brick in 1873 and these bricks are still in successful service in spite of being laid on a very poor foundation (boards).

In 1875, the town of Bloomington, Illinois, paved several blocks with brick which successfully withstood 20 years service before they were worn out.

In both of these pioneer experiments the bricks were only hard-burned building bricks that were very inferior to the present paving-bricks. They were looked upon with so much doubt and uncertainty that no further paving was done with brick until 1883, when Wheeling, West Virginia, put down some modern paving-brick, which were made from an impure fireclay. As the Wheeling venture promised to be a success, Decatur, Illinois, also laid some brick pavements in 1883. In 1885, there was sufficient confidence in brick that it was laid in Stubenville, Zanesville and Columbus, Ohio. Since then it has steadily grown in favor and has shown a phenomenal development within the last five years, especially in the smaller cities.

Although Philadelphia adopted brick for its residence streets seven years ago, the largest cities with their characteristic conservatism, have delayed the adoption of brick, as some of the earlier pavements were by no means an unqualified success, from either soft or brittle brick. Experience and study have resulted in a marked improvement in the quality of paving-brick, so that within the past three years it has been adopted by all the large cities in the country.

In the development of the industry in this state St. Louis showed commendable enterprise in making experiments on three different

kinds of paving-brick in 1880, though all of them were failures. In the following year, another experimental lot (Sattler) was tried that was a success, as the brick satisfactorly withstood the heavy traffic of one of the principal downtown streets (Second and Pine). Though this second experiment was a success, the person who made the brick was in no financial condition to engage in this manufacture or able to successfully make a reasonable percentage of good brick. On account of this uncertainty in their reliability St. Louis abandoned the use of paving brick until 1895, when it was adopted for the alleys and residence streets. It promises to become the favorite pavement of St. Louis on account of its cheapness and excellence.

Kansas City adopted paving brick in 1889, since which time its use has rapidly grown, although not always successful on account of inferior brick having been used.

St. Joseph began the use of paving-brick in 1888, since which time over 100,000 square yards have been laid. The bricks were made in a yard at the southern end of the city, from a shale bank that overlooks the Missouri river.

Springfield began using paving-brick in 1890, and now has about three miles in use. On Boonville street it is exposed to heavy traffic on a 7 per cent grade, where after four years service it is reported in good condition with no repairs. The brick are shipped from Pittsburg, Kansas, Fort Smith, Arkansas, and Deepwater, Missouri.

Sedalia adopted paving-brick in 1891, and paved several streets and alleys with brick from Moberly, Knobnoster, Kansas City and Atchison. It has proved very satisfactory, as care has been taken to carefully test and inspect the brick, and little attention in the way of repairs has been required. The brick are laid on a 6-inch cement concrete foundation and cost from $1.78 to $2.12½ a square yard.

Hannibal began using vitrified brick in 1891, which were first imported from Galesburg, Illinois, and lately from Moberly, in this state.

Vitrified bricks are also used at Moberly, Chillicothe, Louisiana, Clinton and Rich Hill.

DEFINITION OF VITRIFIED BRICK.

As there is a lack of harmony as to what is meant by vitrified brick it is well to specifically state the meaning that is usually attached to the term by the brick trade. A vitrified brick is one that is burned so hard as to be almost non-porous, has a close, dense, compact structure, a very high degree of hardness, and the individual particles of the clay are no longer visible even with a lens. If the brick has been slowly cooled it is found to have a crushing strength that exceeds

granite, and a toughness that is nearly as great as that stone, neither of which properties are approached by the building brick or fire-brick. If vitrified brick are made from shales or common clay, and are burned so hard as to be glassy, when broken, they are found to be not quite so hard nor nearly so tough as when burned at a slightly lower heat, which latter produces a fracture more like stone than glass. In both cases, however, the brick is vitrified, though only slightly or incipiently in the one case and completely in the other. The ideal stage of vitrification is the "stoney" one, as that is found to give a maximum of strength and toughness, with such a slight porosity as to be absolutely safe from the disintegrating action of frost.

CLAYS USED FOR PAVING-BRICK.

The clays used for the manufacture of vitrified paving-brick are mainly shales and impure fireclays, or those which combine a ready fusibility (vitrification) with great toughness and density. Occasionally common surface or yellow clays are used, although they never make a high grade brick, as they are nearly always, at least in Missouri, either too silicious or calcareous to answer for this purpose. At present the shales are exclusively employed in Missouri for making paving-brick, and about 110,000 tons a year are used, which have an average value of about 25 cents a ton delivered at the factory, or an annual value of about $27,500.

The primary requisite of a paving-brick clay is a ready fusibility which is found in those clays that are high in such impurities as iron, soda, potash, lime and magnesia and the greater the amount of the first three of these impurities, the more satisfactory as regards the ease of vitrification. In addition to readily vitrifying the vitrified ware must possess an unusual strength and toughness which greatly exceeds that required of any other kind of brick. This second requisite is more important than the first in Missouri. Although the state is very rich in clays so impure as to readily vitrify the number that also makes a brick tough enough for street-paving is comparatively small. The pure fireclays if very hard-burned, usually make a very tough brick, but they are porous and more or less spongy, as they cannot be successfully vitrified. When sufficiently impure as to enable them to be vitrified with a heat that is readily obtained in a kiln they usually make a very satisfactory grade of paving-brick. The best paving-brick are made from the shales, as these usually possess the requisite impurities to make them readily vitrify and often have the physical properties that result in making a very tough brick. The toughness required in a paving-brick very largely depends on the traffic to which it is exposed, and

this must be kept prominently in view in investigating clays for paving purposes. The traffic in the wholesale districts of St. Louis is so heavy as to wear out the most durable of all pavements or granite, in fifteen to thirty years, and the best paving-brick thus far made would probably last not much more than half that time. This represents however, the almost continuous passage of heavily loaded teams with frequently heavy grades, and is so severe as to wear out any pavement in time. On the other hand the traffic on the up-town residence streets of St. Louis is moderate in amount, and light in character and under such conditions, high grade paving-brick is likely to last from fifteen to thirty years. In the smaller cities and towns, where the traffic is usually still lighter the durability would be even greater. A paving-brick of the high quality necessary to withstand the heavy traffic of St. Louis would not be necessary on the streets of the smaller cities and towns, and there are many clays that would make a brick tough enough for light traffic that would soon wear out in a large city. Local brick-yards may therefore be able to cheaply supply a brick good enough for the light traffic of towns, while special and exceptional clays and shales are necessary for the very tough brick required for metropolitan traffic.

Another important factor, which is frequently overlooked, is that it is more expensive to make a high grade brick than one of moderate quality when both are made from the same clay, as more care, time and a larger plant, especially kilns (the most expensive part of plant) are required.

PHYSICAL PROPERTIES OF PAVING-BRICK CLAYS.

The physical properties required of a clay to make a satisfactory paving-brick, whether it be a surface clay (residual, glacial, or loess), or a shale, or impure fireclay, are the following:

(1) Sufficient plasticity to enable the clay to be readily moulded. If the clay is so lean as not to admit of being worked into a continuous bar by an augur machine it cannot compete in cost and quality with the clays that can be thus cheaply worked by the continuous system, unless a fat or bond clay is available to furnish this requisite plasticity. It is desirable that the clay should be only moderately plastic or have a tensile strength when dried of 100 to 150 pounds to the square inch. If too fat or too high in tensile strength, above 200 pounds to the square inch, it is liable to laminate badly in moulding, and check in drying, thus making an inferior brick. The latter fault can be corrected, however, by mixing with a lean or non-plastic clay, or with "grog" or sand, though the resulting brick is never so strong

as when made from a single clay, and there is always danger of not getting a perfect mixture, resulting in brick that are not uniform in strength or size.

(2) The shrinkage in air-drying or burning should not be excessive, or more than about 12 per cent. If too great it causes checking or cracking in the drying and burning, and if the fire-shrinkage is very large, it greatly increases the difficulty in burning, from the rolling and splitting that occurs in the kiln unless very carefully burned.

(3) The speed in drying should enable the brick to be run through the dryer in from 24 to 36 hours, if the dryer is properly designed. If the clay is such as to require over two days in drying (a few need five to six), it greatly increases the cost, and requires a very large outlay in excessive drying room, if a sound, unchecked brick is to be secured.

(4) The speed in burning should permit a vitrifying heat to be put on in five or six days. If the clay is so tender as to demand a very gradual firing it greatly increases the cost and makes it difficult to compete with other clays.

(5) The point of incipient vitrification, to which all paving-brick clays should be brought, should be low. It should readily be obtained in an ordinary kiln, or from 1,500° to 2,000° F. If the clay is so refractory as to require a higher temperature than 2,000°, it adds to the cost.

(6) The point of viscous or scoriaceous vitrification should be at least 300° and preferably 400° F., above the point of incipient vitrification. Unless there is ample margin for the kiln-burner to vitrify the brick without melting them there is a heavy waste on soft, underburned, or mishappen and warped overburned brick, since it is impossible to control the heat of the kiln within a narrow margin.

(7) It is desirable that the density of the clay, both before and after burning, should be as high as possible, since high density is an important factor of durability.

(8) In some cases it is desirable that the clay should burn to a dark color to meet the prejudice of some engineers; for there is a wide-spread impression, that is not without some foundation, that good paving-bricks are dark in color, and consequently light bricks are often rejected without being given a trial.

(9) The crucial test of a paving brick is its toughness or strength, and it is the primary requisite of a paving-brick clay that it should burn to a very strong tough brick. This strength is determined by a series of tests in the laboratory, which satisfactorily and promptly gives this information, so that it is not necessary to wait the results of years of travel to learn about this important matter.

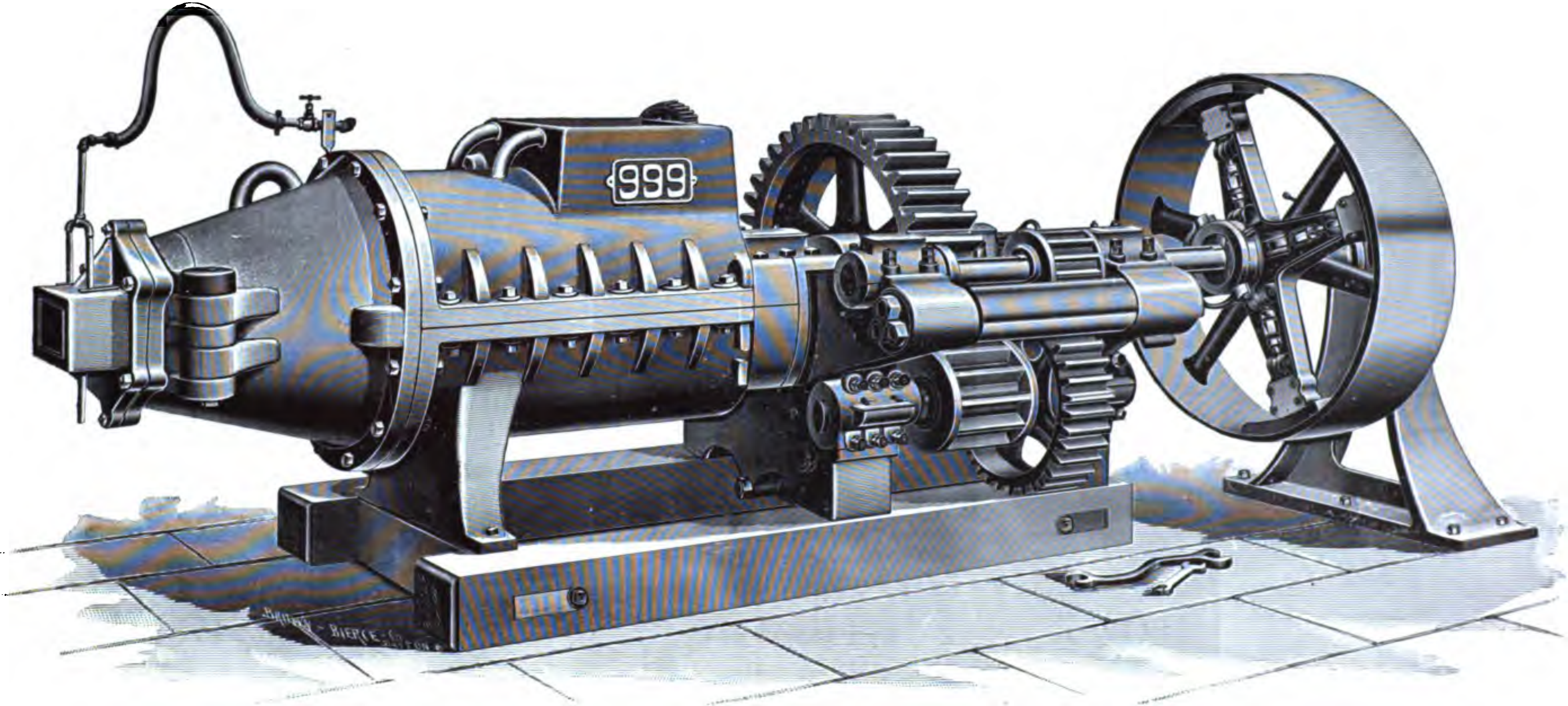
CHEMICAL PROPERTIES OF PAVING-BRICK CLAYS.

As previously mentioned, the chemical composition of the clay is always subordinate to its physical properties and this is preeminently true of the paving-brick clays. While the percentage of fluxing impurities has a very great influence on the fusibility which is the primary requisite of a vitrified brick clay, the specific gravity and fineness of grain have also a very great influence. Furthermore, the analyses as given by chemists only state the total quantity of the fluxing constituents without discriminating as to their conditions and combinations, which again greatly modify the fusibility. The chemical composition of a vitrified brick clay is therefore of value only in indicating the probable vitrifying point of a clay which in this case should be readily obtained in the heat of an ordinary down-draught kiln. If the clay is coarse-grained, and contains less than five per cent of fluxing constituents, especially if the specific gravity is over 2.27, this will not be possible, and such clay will not answer for vitrified brick though it may be valuable for firebrick or stoneware. If the impurities exceed five per cent, especially if accompanied by a fine grain and a density below 2.2 it will probably vitrify successfully and the higher the amount of the fluxing impurities, the more readily will it vitrify. A study of the Missouri and other clays suitable for vitrified brick gives the following range of composition:

*Composition of Vitrified Brick Shales.**

	Minimum per cent	Maximum per cent.	Average per cent.	Totals average.
Silica (SiO_2)	49.0	75.0	56.0	
Alumina (Al_2O_3)	11.0	25 0	22.5	
Ignition, loss (H_2O, S, CO_2)	3 0	13.0	7.0	
Moisture (H_2O)	0.5	3.0	1.5	
Total non-fluxing constituents				87 0
Iron sesquioxide (Fe_2O_3)	2.0	9.0	6.7	
Lime (CaO)	0.2	3 5	1.2	
Magnesia (MgO)	0 1	3.0	1.4	
Alkalies (Na_2O, K_2O)	1.0	5.5	3 7	
Total fluxing constituents				13.0
Grand total				100.0

*Deduced from fifty reliable sources. There are many analyses in the current literature that purport to be of vitrified brick clays and shales which differ greatly from the above; but they have been found to be misapplied analyses of burnt brick, kaolins, fire-clays or other material not used for vitrified brick.



A STIFF-MUD AUGER BRICK MACHINE.

This range shows that there may be a great variation in the composition of clays suitable for the manufacture of vitrified brick, though as a matter of fact, the majority of clays used at the well known paving-brick centers approximate very closely to the above average, and this can be safely taken as the desirable composition of vitrified brick clay.

MANUFACTURE OF VITRIFIED BRICK.

Digging the Clay. The digging of vitrified brick clays does not differ materially from other clays, except that the shales are frequently found in such large thick bodies as to make a steam shovel desirable, if the size of the plant will justify the large production of this economical machine.

Crushing the Clay. As vitrified brick are usually made from shale and as shale is generally hard and tough, the dry-pan is generally used for crushing, as experience has demonstrated that this is the cheapest and most satisfactory machine for this purpose. The dry-pan is a large Chilian mill or revolving iron pan, that is usually 9 feet in diameter, in which are a pair of heavy iron rolls or mullers that are about 4 feet in diameter, 12 inches wide and weigh about 4,000 pounds apiece. The outer flooring of the pan consists of grates, with slots, one-sixteenth to one-fourth of an inch in width, according to the fineness that the clay or shale is to be crushed, and the shale is retained in the pan until crushed fine enough to pass through these grates. The machine is very simple, and satisfactory, as it has a capacity of 5 to 10 cubic yards of clay an hour. Rolls of various patterns and centrifugal disintegrators have also been used for crushing shale, but have not proven very satisfactory, as most shales are so tough that much of the material has to be returned as "tailings," for recrushing.

Screening. The grates at the bottom of the dry-pan are liable to break and the slots are constantly wearing larger, so that a second screening is necessary to ensure the delivery of fine material to the brick machine. The capacity of the crusher is largely increased, especially in wet weather (when the clay is sticky) by using coarse grates. Special screens are therefore used, through which all the clay passes after being crushed, that are situated in a soft or overhead screenhouse, above the factory floor.

Two types of screens are employed, rotary screens or trammels, and flat screens or riddles. The trammels or revolving screens are more compact, and have a larger capacity, while the fixed inclined screens are simpler to clean and repair. In both cases it is necessary to jar the screen with a knocker or hammer device, to prevent the lodgment of coarse particles in the screen holes. Flat, shaking screens

do away with this knocker, but take considerable power to run them, and are liable to shake themselves to pieces. In spite of knockers, brooms and flaps, to automatically clean the screens, it is usually necessary to have a boy slap them clean with a piece of leather. The finer the clay is screened, the better will be the resulting brick, as coarse particles affect the homogeneity and strength. Usually the size of screen used is from 4 to 8 meshes to the linear inch, though 10 or twelve would give better results in most cases. Screens are made of woven wire and punched sheet steel, the latter being the more satisfactory, especially if the holes are punched in the shape of a slot about one-half inch long.

Pugging the Clay. The crushed and screened clay, as a fine powder, is next mixed with water to a plastic mass in a pug-mill. The type of pug-mill usually employed is a long horizontal box or trunk, within which revolves a heavy shaft armed with wide blades or knives set at a slight angle. The clay and water are fed at one end and are mixed together and worked forward by the slowly revolving knives until extruded at the other end as a homogeneous plastic mass. Most pug-mills are too short to thoroughly mix the clay, being only 6 to 8 feet long, whereas a length of 10 to 12 feet is usually necessary, and preferably even greater.

Moulding. The pugged clay is fed to what is known as a stiff-mud brick machine, in which the clay is forced through a die the size of a brick, by either a continous working auger, or a reciprocating plunger driven by steam or gearing. The plunger pattern is generally used for tiling or sewerpipe, while the auger machines are employed for vitrified brick (plate XXVI). The bar of clay is cut into brick by automatic cutting devices and carried along a belt to the off-bearers, who unload them on to small iron dryer cars (plate XXVII.) The auger machines are made of various capacities, from 20,000 to 100,000 a day of ten hours, and have proved very satisfactory if the clay is not worked too stiff. Two sizes of dies are used, one about 2½ by 4 inches, which makes an end-cut brick and the other about 9 by 4 inches, which makes a side-cut brick. The end cut brick have hitherto been the standard for pavers, but since the recent adoption of repressing, the side-cut brick have become very popular. The side-cut brick are more easily repressed, and from recent experiments they seem to be slightly stronger. Great caution should be taken, however, before deciding on this matter, for some clays laminate more in the one case than in the other, and there is no fixed rule on this question. A badly laminated side-cut brick is very serious in a paving brick though not of great importance in a building brick. These laminations are always present,

MAKING PAVING BRICK.

to some extent, in all stiff-mud machine ware, as they result from the varying speeds of the clay in different parts of the cross section of the bar. They are increased in very plastic clays, or if the clay is pugged too soft, or if the machine is not properly fed with clay. They are decreased by pugging very stiff, and keeping the machine well filled with clay, and are nearly absent in lean clays. If not very pronounced experience shows that they are not very detrimental.

Attempts have been made to make a vitrified brick by the dry and semi-dry processes, in which only enough water is added in pugging to make a damp, pulverulent mass, which is moulded into brick in a powerful press. The results have thus far not been successful, as the laminations are still found to be present, though now flat instead of concentric, and it is found very difficult to burn more than a small percentage of No. 1 grade.

Repressing. The stiff-mud bricks were formerly dried and burned as they came from the auger machine, but in recent practice they are repressed on leaving the auger machines which greatly improves their uniformity in size, and fills out the edges and angles. This is done on a special machine, known as the repress, in which the brick are put into an oiled box and subjected to the pressure of a vertical moving die. These repressed bricks are more shapely and freer from laminations, while they are somewhat denser, and usually slightly stronger, than the unrepressed bricks. It involves a liberal consumption of oil, which has to be used on the dies, boxes, and slides, to prevent the adhering of the clay, and adds considerably to the cost.

Drying. The bricks are piled from the repress in open checker work on small iron cars that are usually provided with friction roller bearings. The cars are then run into long tunnels that are heated by either steam pipes, open fires, or oil. The tunnels are usually about 100 feet long, and have from one to four tracks, and a current of fresh air is drawn in over the steam pipes or fires, by either high wooden stacks or exhaust fans. Clays vary greatly in the speed with which they can be dried. Some can be rapidly dried in 20 hours, while others need from 40 to 100 hours to avoid the checks or cracks that are liable to result from too rapid drying. The time required to dry off a clay without injury to its strength or checking, should be determined on a practical scale in designing brick yards, to avoid the very common trouble of having insufficient dryer rooms, and finding out when it is too late that the bricks need a longer time in drying.

Burning. Vitrified brick should be burned in down-draught kilns, for the up-draught kiln is unable to produce a large percentage of No. 1 brick. Various types of down-draught kilns are employed, which

are designed as circular or "bee-hive" kilns, and as long rectangular or "square" kilns. The round kilns are very largely used in Ohio, the center of the vitrified brick industry, on account of the ease of burning, the small cost of the kiln and cheapness of maintenance. Plate XXVIII shows a smokeless bee-hive, or down-draught kiln as used by the Standard Tile Co. They have small capacity, however, from 25,000 to 80,000 brick, and are not generally used in Missouri, or the more recent western plants, where the large rectangular kilns are employed which are of much greater capacity, or from 150,000 to 300,000 and are more convenient for setting and emptying. There are several types of the down-draught kilns, most prominent among which is that known as the Eudaly in which each kiln has a series of small stacks as shown in plate XXIX. A view of the interior of a down-draught kiln is given in plate XXX. Other kilns like the Graves, Rutter and Alsip have a large high stack in common, with which they are connected by underground flues. Combined kilns, or those which can be alternately worked up-draught and down-draught, have not thus far proven a success, though many attempts have been made to attain this coveted object.

In making vitrified brick the burning is the most important and critical part, for if heated too hot, the product wilts and loses shape; while if underburned it is too soft to use for paving purposes. It therefore calls for the best of kilns and excellent management, in order to produce a large proportion of No. 1 brick. Even with good kilns the percentage of No. 1 brick is sometimes less than 60, and seldom exceeds 80 per cent when carefully graded. The brick are set very open, and usually five over two, and often in united independent cobs, to avoid distortion in rolling. The burning of the kiln should be so managed as to first throw the heat to the center and keep the center closed throughout, to avoid the huge rifts or splits that otherwise often occur in the excessive shrinkage that always results in burning pavers. The vitrified brick are burned entirely with coal, as color being of no importance it is unnecessary to water-smoke with wood, as is the case with building brick. The water-smoking period of burning when the chemically combined water is driven off, takes from 2½ to 5 days, and the firing or high heat is maintained 4 to 6 days longer, which brings the entire kiln to about a cherry red heat, or from 1,600° to 1,900° F. Impure fireclays require a higher heat, or from 1,800° to 2,300° F. On completing the burning, the kiln should be slowly cooled down by tightly closing the doors and dampers, and should be allowed from 6 to 12 days for annealing or toughening, before being emptied. The slower the cooling, the tougher will be the brick. Most of the brittle

SMOKELESS ROUND DOWN-DRAUGHT KILNS.

brick on the market to-day are due to the lack of annealing. If the brick are thoroughly vitrified they attain a condition of incipient pastiness and the lower courses of the kiln become "kiln-marked" from the indentations due to the weight of the overlying brick. To prevent these kiln marks from becoming too deep, the brick are set from 24 to 34 high, according to the fusibility of the clay, and the "settle" or total shrinkage amounts to from 16 to 24 inches. If cold air strikes the hot brick, from cleaning the fires or from cracks in the kiln walls it more or less chills and hair cracks the brick and such air checks always show a glassy surface. On opening a burned kiln, the top of the brick should show a uniform, even settle, and be free from large splits or rolls which injure the shape of the brick. The top course or two will be found to be covered with dust and ashes carried over by the draught and are often more or less air checked. These top brick are excellent for sewers, on account of their intense hardness and practical non-porosity. They amount to from 0 to 6.0 per cent of the output. Beneath the top brick, to within five to twelve courses of the bottom, should be No. 1 pavers, which amount to from 50.0 to 90.0 per cent. Within one to twelve courses of the bottom are No. 2 brick which have not received enough heat to burn No. 1 grade. These make excellent foundation brick for either buildings or pavements and amount to 10.0 to 30.0 per cent. On the bottom of the kiln, are still softer brick, from further lack of heat, that are graded as "No. 3" or "builders," and are sold to the building trade as "hard" brick; they amount to from 1.0 to 10.0 per cent. Continuous kilns have been used for vitrified brick, but have not yet proved a success on account of the difficulty of maintaining the feeding parts (from the excessive shrinkage) and the low percentage of No. 1 quality produced. Experiments, however, are being made which may result in this kiln being a success for vitrified brick which will be a great advantage on account of its well known economy in fuel.

PHYSICAL PROPERTIES OF VITRIFIED BRICK.

Color. The color of a vitrified brick is a valuable guide in judging of the degree to which the brick has been burned, after one is familiar with the behavior of the particular clay of which they are made. It is a dangerous guide in judging the value of unknown brick, as clays differ so greatly in color, after burning. As a broad, general statement, the harder a clay is burned, the darker it is, but all dark brick are not necessarily hard-burned, nor are all light colored brick necessarily underburned. The impure fireclay brick are usually light in color, or of various shades of cream to buff, while the shale and

common clays usually burn to reds, browns and black. A custom still prevails in the Ohio valley of artificially producing a dark color, and glassy surface by salt-glazing the brick, similar to sewerpipe and some of the earliest of the Missouri vitrified brick were similarly treated. As the glaze is superficial, it soon wears off, and adds nothing to the durability of the brick, while it greatly increases the difficulty of inspection, as it is necessary to break the brick, to see that it is properly vitrified. The practice, in consequence, has almost become obsolete in Missouri, and is dying out in the Ohio districts.

Structure. In structure a vitrified brick should be close, dense, and homogeneous. It should be free from cracks, ragged edges, due to obstruction in the die, and be reasonably perfect in shape. Kiln marks or indentations from over-weighting in the kiln, should not be deep, or over one-fourth of an inch. As the durability of a brick pavement depends on maintaining a smooth surface, any warping or distortion that prevents this should bar out the brick.

Hardness. The hardness of a vitrified brick, next to its toughness, is its most important qualification, and a thoroughly vitrified brick has a hardness exceeding any stone or metal. Underburned brick are conspicuously soft, and in consequence soon wear out, forming ruts, if used for paving. The hardness is best determined by Moh's scale of hardness, in which No. 6 is feldspar, or the principal mineral in granite, and No. 7 is quartz. Thoroughly vitrified brick lie between 6.5, and 7, and any brick softer than 6 is not durable enough for paving.

Porosity. The porosity of vitrified brick is an excellent clue to the degree of vitrification. For thoroughly vitrified shale brick are found to absorb only one to two per cent of water and imperfectly vitrified impure fireclay brick from two to six per cent. Common hard-burned building brick absorb five to ten per cent, and salmon brick from fifteen to thirty per cent. The test is usually made by soaking a a thoroughly dried whole brick in clear water for 24 hours, wiping dry, and weighing, and the increased weight is used as an index of the porosity. It is preferable to take small chips, which are easily and quickly dried, (which is always uncertain with a whole brick) and weighing on a chemical balance, which is much more accurate.

The absorption of vitrified brick is misconstrued by many engineers and is used as a test of the ability of the brick to withstand the action of frost. In consequence arbitrary lines are drawn at 1.5 and 2.0 per cent which must not be exceeded on the assumption that frost would disintegrate the brick. The facts are that well vitrified brick has a strength so great as to resist the disrupting action of frost, in spite of an absorption that greatly exceeds the arbitrary limit drawn

RECTANGULAR DOWN-DRAUGHT KILNS.

by some engineers. This is well illustrated by the Charleston brick, which are still in successful use after twenty-two years of service, although they absorb 4.5 per cent of moisture in 24 hours. The first Bloomington brick, with an absorption of 4.3 per cent, are just being renewed after twenty years of service. The Sattler brick, that successfully withstood seven years hard service in St. Louis, absorbed 5.0 to 5.4 per cent, but were not in the least affected by frost. The first two brick were made from common surface clays, the latter from fireclay but all were made by the mud process.

Density. Density or specific gravity is a very important factor in vitrified brick, as other things being equal, the denser the brick the more durable it is. The density of the burned brick is usually about that of the clay, as the loss of the chemically combined water is about balanced by the shrinkage. The specific gravity of the Missouri shales range from 2.15 to 2.55, and average about 2.38. The Missouri coal measure fireclays range from 2.20 to 2.55, and average about 2.40; and the latter potters' and other fireclays range from 1.90 to 2.20. Vitrified shale brick range from 2.20 to 2.40, and the impure fireclay brick from 2.05 to 2 25.

Crushing Strength. Vitrified brick is one of the strongest materials known for withstanding crushing, often exceeding the crushing strength of granite. The strongest brick are the thoroughly vitrified shale brick, which run as high as 30,000 pounds to the square inch, while in other cases, they go as low as 4,000 pounds, and this sharply calls attention to the great variation to be found in different shales. Usually shale brick range from 10,000 to 20,000 pounds to the square inch. The impure fireclay pavers fluctuate less, ranging between 6,000 and 14,000 pounds. On account of this very high crushing strength, which is only exceeded by a few of the metals, brick pavements never yield by crushing, and this factor is only determined by engineers as a relative guide rather than for its intrinsic value.

Cross-breaking Strength. This factor, which is also known as the modulus of rupture, is determined by supporting a brick between two knife edges set six inches apart, and breaking it by a knife edge applied in the middle, the knife edges all being rounded. This determines the strength as a beam, on the assumption that it may be only supported on its ends in the street. Good grades of brick are found to have a strength far above any load they are exposed to in practice, as the resistance for each square inch of section, under these conditions, is found to range from 1,000 to 3,000 pounds.

Toughness is the most essential requirement of a paving-brick, as it is this factor that resists the blows of the horse's hoof and the

abrasion of the wagon tire. It is determined by putting the brick in a foundry rattler or tumbler, and rotating it for a fixed period. The rolling, sliding, and tumbling in the rattler rapidly wears the brick, and the toughest of brick or stone lose from 5.0 to 15.0 per cent after one hour's rattling, while poor grades lose from 15.0 to 50.0 per cent. It is the most valuable test for determining the value of a brick for street paving and is rapidly and easily made. But the results obtained will vary greatly according to the method by which it is carried out. As experience is obtained and more care is taken with better equipped plants, vitrified brick should steadily improve in quality when tested by the rattler. Possibly they can be made with a toughness closely approaching granite, which has already been attained in a few instances, when the two have been tested side by side in the rattler.

TESTING VITRIFIED BRICK.

Eye Examination. Brickmakers and engineers who have had a wide experience with vitrified brick are able to quickly and satisfactorily form an opinion as to the value of a vitrified brick by a careful eye inspection, when assisted by a hand hammer. Careful inspection quickly shows whether the brick have been properly made, uniformly burned, thoroughly vitrified, and carefully sorted while the free use of the hammer quickly discloses whether the brick are tough or brittle. To do this however, good judgement and experience is imperative, while it does not admit of being expressed in numerical terms, and the personal equation is excessively prominent. To overcome these last objections, and to permit of reliable and definite comparisons, certain laboratory tests have been devised. A complete examination of a vitrified brick in the labratory should consist in the determination of the following factors:

(1) Density, or specific gravity. (D)
(2) Absorption, or porosity. (A)
(3) Crushing strength. (C)
(4) Cross-breaking strength. (B)
(5) Hardness. (H)
(6) Rattler loss. (R)

In making a careful and complete comparison of different bricks, all these factors should be considered, as they all have an important bearing on the quality. But as the rattler test is of much greater value than all the others combined, only this, with perhaps the absorption and hardness, are determined in the frequent tests required in municipal engineering. To properly make the density and absorption test requires a chemical balance, costing from $20.00 to $50.00, though

INTERIOR OF A RECTANGULAR DOWN-DRAUGHT KILN.

a good grocer's or druggist's balance is often substituted. To make the crushing and cross-breaking tests requires an expensive testing machine, of at least 100,000 pounds capacity. The hardness test is made with Nos. 6 and 7 of Moh's scale of hardness (worth 50 cents and the foundry rattler is worth from $25.00 to $100.00). The latter is easily made out of oak or maple, and is usually found in any iron foundry. The rattler can be run by hand power, but is preferably driven by a belt from a line of shafting at uniform speed. The crushing test should be made edge-wise, on a half brick, after the edges have been ground perfectly smooth and parallel, and at right angles with the axis of the testing machine. It is very important to secure these true parallel surfaces in the crushing test, as the results are much higher and more uniform than when imperfect substitutes as plaster of Paris, paper, wood or lead are employed. The cross-breaking strength is determined by the formula:

$$f = \frac{3\,Wl}{2\,bd^2}$$

Where

f=modulus of rupture, in pounds to the square inch.
W=breaking load, in pounds.
l=length between bearings, in inches.
b=breadth of brick, in inches.
d=depth of brick, in inches.

The rattler test should be made in a polygonal cylinder 24 to 30 inches in diameter, with a length of 36 to 42 inches, and run at about 25 revolutions a minute. It should be hung on trunnions and the brick should occupy about 25.0 per cent of the volume of the rattler. If enough brick are not being tested to occupy a uniform volume, the deficit should be made good from a stock of standard brick furnished by a reliable company. The rattler is run at a uniform speed for about an hour, when the difference in the weight of the brick before and after rattling gives the loss resulting from this severe action. The brick are so rounded and chipped after the hour's rattling that it is often difficult to recognize them, and small punch marks are made on the middle or end faces, to identify them. Foreign matter, as scrap iron, granite blocks or castings are sometimes added, but as these introduce conditions that are very difficult if not impossible to reproduce, and are totally unnecessary, they should be omitted, and nothing added to the brick being tested, except a standard brick for comparison. At least 5, and preferably 10 of each kind of brick to be tested should be put in the rattler at a time, and the results averaged for subsequent use, which the closer the results agree, the higher it speaks for the uniformity of the brick. The relative rating of different brick

after these tests have been completed is obtained from fromula (1), when the tests are complete, and from formula (2) when incomplete.

$$(1)\ V=(18-R)5+(7-A)2+\frac{T}{220}+\frac{C}{1000}+\frac{10}{3.25-D}+\frac{10}{7.75-H}$$

$$(2)\ V=(18-R)6+(7-A)4+\frac{T}{220}+\frac{C}{1000}$$

Where

V=An arbitrary comparative rating of the brick.
R=Rattler loss.
A=Percentage of absorption.
C=Crushing strength to the square inch.
T=Modulus of rupture to the square inch.
D=Specific gravity.
H=Hardness, by Moh's scale.

USES OF VITRIFIED BRICK.

Vitrified brick are especially adapted to the following uses:

1. Sewers.
2. Foundations and side-walks.
3. Chemical tanks.
4. Street-paving.

Sewers. The cutting action of sand on sewer bottoms is very severe, and rapidly wears them out of there is much water or grade. This entails a heavy expense for maintenance in the renewal of the bottoms, if common building brick are used. As vitrified brick are very much harder, as well as stronger and much less porous than building brick, they are very much more durable for sewer construction, and are now being largely substituted for common brick. Where cities are so fortunate as to have good grades for the sewers as St. Louis, Kansas City and St. Joseph, and the sewers and streets are both made of vitrified brick, the very cheap and efficient hydraulic system of street cleaning can be employed. This system, which does away with large gangs of sweepers, shovellers, and carts, and replaces them by a hose crew of three men and a line of hose, is not only by far the cheapest system of cleaning, but decidedly the most efficient and thorough. But it requires pavements of brick or granite, which can stand the use of a powerful stream of water without injury; and a durable lining to the sewers to withstand the scouring action of the sand, in addition to sufficient grades to prevent the deposition of the sand in the sewers.

Foundations and Sidewalks. The very low absorption and high crushing resistance of vitrified brick make them admirable materials for foundations of bridges, high buildings or other places requiring great strength. They were used in the piers of the new Chicago, Burlington and Quincy railroad bridge across the Missouri river, near St.

Louis, and in the new 16-story Chemical Bank Building, St. Louis. These bricks also make a very ornamental front (when rock-faced) which at present is very popular. For the same reason vitrified brick is preferable to building brick for sidewalk service, as common brick is very short-lived if the travel is heavy.

Chemical Tanks. For lining chemical tanks, vats, or other places where corrosive fluids have to be handled, vitrified brick has proven very satisfactory, as it is unaffected by acids and other chemicals.

Street Paving. The principal field for vitrified brick, which is being rapidly occupied, is for street paving, for which it is pre-eminently adapted on account of its low first cost, cheap maintenance, easy traction, cleanliness and slight noise. In Missouri there is only one cheaper class of good pavements, or macadam, but this is very expensive to keep in repair if the travel is heavy and always troublesome from either mud or dust unless maintained in an ideal condition, which is seldom found outside of park service. In cheapness of maintenance the only pavement that can compare with it is granite, but the first cost of granite is very much greater, and it is very much rougher, resulting in much more noise and greater resistance to traction, though more durable. In case of traction, brick is only exceeded by sheet asphalt, but the latter is more expensive to build, very much more expensive to maintain, affords a very poor footing for horses and should not be used on grades exceeding 5.0 per cent, while the joints of the brick enable it to be used on the heaviest grades. In cleanliness brick has only one rival, or asphalt, but it hast he advantage that it can be cleaned by the hydraulic system, which injures sheet asphalt both chemically and mechanically. The very low absorption of vitrified brick makes it very desirable from a sanitary point of view, as the filth and slime is not retained as the case of wood, macadam, or the coarse joints of stone blocks. As regards noise, brick is not as noiseless as macadam or wood, but is free from the sharp click of asphalt and the dull rumble and low roar of granite blocks or cobble stones.

A criticism that is frequently heard from those who have no personal familiarity with paving materials is the lack of homogeneity in vitrified brick. It is self-evident that either soft-brick or brittle brick, though made from the best of clays will prove unsatisfactory. But this is the same trouble that confronts every kind of paving material, as none can be relied on if not inspected and discrimination exercised. Granite is subject to decay which renders it soft, and much trouble was experienced in its early use in St. Louis, in preventing soft or short-lived material from being laid in the streets. Asphalt requires great care in the mixing of the asphaltum, bitumen, oil, limestone, sand

and other ingredients, and still greater care is required in the handling and mixing to ensure satisfactory results. In fact, a reliable asphalt is so difficult to obtain that one company has almost had a monopoly of the business of the entire country for years. Wood varies greatly in quality, and requires very careful inspection to keep out sapwood, heart-wood and decayed wood. Macadam and Telford are very unsatisfactory if the broken rock is not homogeneous and uniform as it becomes full of ruts if the rock is too variable in size or intermixed with softer material.

Durability. High grade vitrified brick have not yet been worn out, and it is therefore premature to discuss this question. An inferior quality of brick are still in use after 22 years of service in Charleston, West Virginia, and a still poorer quality of brick is being renewed at Bloomington, Illinois, after 20 years service. It is true that in both cases, the towns are small and therefore the traffic was probably not very heavy. It is also true that brick have been reported as unsatisfactory in several places, this state not excepted, but it should be remembered that comparatively few clays or shales make a high grade paving-brick. This was not at first appreciated, and many of the early brick were sent out either very brittle from imperfect annealing, or too soft from insufficient burning, which is not surprising when the infancy of this industry is considered and the amount of experience that has had to be acquired in costly practical tests. When the evidence of the cities that have been using it for the past ten years is discussed with discrimination, and especially where the brick have been made within the last five years, during which time marked improvements have been made, it strongly indicates that properly made vitrified brick will prove very durable under all but the heaviest traffic, and the evidence is encouraging that with the improvements already in sight, a quality can be made that will stand even the severest traffic of our large cities. The brick will not endure as long as granite, but the lower first cost, much easier traction, greater cleanliness and less noise, may well repay a more frequent renewal than would be necessary for granite.

PAVING-BRICK INDUSTRY.

The paving-brick industry is represented by 13 plants in Missouri, which are all located in the central and western portions of the state where there is an abundance of raw material and where the people have been more active in taking advantage of this excellent, cheap kind of paving. The capital invested in these plants is estimated at $231,800, and their annual output is valued at $347,000. This industry is destined to show a rapid increase since the demand for the

product is rapidly growing as the merits of brick pavements become better known. This increase will partly be met by the growth and enlargement of the present plants, and undoubtedly by some new plants.

ST. LOUIS.

Sattler Paving Brick Co. The first paving brick made in Missouri, and one of the earliest efforts made in the United States to make a brick especially adapted to street-paving, was made in St. Louis about 1876, by George Sattler. As this was the first effort in the state, if not in the United States, to develop the manufacture of vitrified brick as a special industry, the following details are given as mile posts in the early history of what has since developed into a large industry.

Mr. Sattler began exploring the coal measure shales in the northern part of St. Louis county, in the neighborhood of the Chain of Rocks in the year 1873. The associated fireclay seam underlies the greater part of the northern portion of the county, and outcrops at several places near the Mississippi river. It is there overlain by 20 inches of coal which was formerly worked for local consumption. Mr. Sattler in operating a small coal bank on what is now the Schautz farm, became familiar with the underlying fireclay. He tried shipping it to the south St. Louis Zinc Works, and to Lasalle, Illinois, but it did not prove satisfactory. In digging a well on what is now the Meintz farm, about two miles south of the Chain of Rocks, the fireclay was found to have an unusual thickness. Mr. Sattler's attention was called to this new discovery which he followed up by sinking one or two pits. These disclosed from 15 to 30 feet of fairly good fireclay with occasional seams of one to two feet of a very superior quality that answered, and in fact was used, for the very trying service of glass-pots. Attempts were made to sort out the purer pot-clay seams from the large body of less pure clay but the quantity of this high grade clay was too small to be profitable. In order to utilize this great body of second rate quality Mr. Sattler attempted to make it into paving-brick, being inspired by the success of brick pavements in Holland. As Mr. Sattler was by trade a mill-wright, and had had no prior experience with clay until he undertook the development of this tract, with the backing of two capitalists, Albert M. Meintz and John Livingston, of East St. Louis, his progress was slow and unsatisfactory. With this unusual development of 15 to 30 feet in thickness of the fireclay seam, which is usually 7 feet thick, there was a marked difference in the character of the grain, which is here very fine, and causes the clay to check badly in drying and burning. It was therefore very difficult to produce a sound

brick, especially if burnt clay and grog were not used. This expensive experience was acquired by years of experimenting by Mr. Sattler, and the outlay of large sums of money, on the part of his friends. It resulted in the production of brick that were generally unsound from either checks and cracks, or too soft from insufficient burning, though occasionally a few sound brick were made.

In 1878 Mr. Sattler had some of his brick tested, which gave results that were so encouraging that an experimental lot was laid at the west entrance to the Eads bridge, in 1880, with funds raised by the contribution of $50.00 each from one hundred leading citizens. These brick on account of their softness and poor sand foundation, soon wore out under the very severe traffic of the East St. Louis freight teams (probably the heaviest in St. Louis).

Two other lots of paving brick were also given a trial this same year (1880) one of which was a salt-glaze mixture of shale and fireclay made by the Laclede Firebrick company ("blue brick") and the other was a common brick boiled in tar. These also were failures as they were too soft or too brittle to stand the heavy traffic to which they were exposed.

A second lot of the Sattler brick was laid in 1881, on Second and Pine streets where it was exposed to severe traffic. The brick in this lot were very much better and after two years successful service, when they had to make way for a new granite pavement, they were relaid at the northern gateway of the Missouri Pacific freight yard, on Seventh street where some of them are still in use (1895) under heavy traffic. A small factory, with one round down-draught kiln, was built on the Meintz farm, on the Columbia bottom road, to carry out these experiments, and still later they were continued at the glass-pot works of Coffin & Co., at the foot of Ferry street. The final result of years of experimenting, on a naturally unsatisfactory clay, enabled Mr. Sattler to make a good quality of paving-brick, but he found it necessary to partly calcine this particular clay, which he protected by patents covering the process and apparatus. He was never able, however, to make a large percentage of good brick, on account of the refractory nature of the clay, with the consequent difficulty of getting a high enough heat to burn them hard. Mr. Sattler tried various kinds of machinery (auger, plunger, dry-press) and various ways of manipulating the clay, but most of the brick were made on a hand mould of a large or block size that was 9 by 4 by 5 inches. Mr. Sattler was in the midst of the formation of a large company to manufacture paving-brick from this very thick body of peculiar fireclay, when he died, October, 1890, since which time no further efforts have been made to

utilize it. The paving-brick industry has so changed since Mr. Sattler's experiments, that vitrified brick can now be profitably made for $8.00 a thousand, while Mr. Sattler estimated the cost of manufacture of his brick at $20.00.

MONTSERRAT.

Montserrat Mining and Manufacturing Co. This plant was erected in 1886, one mile east of Montserrat station, in Johnson county, on the main line of the Missouri Pacific railroad, but it was burned down in 1890, and has not yet been rebuilt. The following statement is made, as historically it was the first successful paving-brick plant in Missouri, and it presents evidence of good management. It was equipped with a stiff mud Penfield plunger machine of a capacity of 40,000 a day, and also a stiff-mud Wallace brick and terra cotta machine, of 20,000 capacity, and a 9-foot dry-pan. The brick were dried in eight tunnels, with fire places at one end, and a 4-foot exhaust-fan and a 48-foot stack at the opposite end, to produce a draught. The plant was run by a 15 by 30-inch engine and two 4 by 24 feet boilers, with a special 10-horse power Westinghouse engine to run the fan. The burning was done in two rectangular 18 by 50 feet down-draught kilns, and two 24 by 60 up-draught clamp kilns. The product was mainly paving-brick, but drain-tile, fire-proofing, and terra cotta lumber were also made. The product was shipped to Kansas City, Sedalia and other points on the Missouri Pacific railroad. The clay was obtained from a bank 100 yards south of the works, and consisted of 8 feet of impure fireclay and 4 feet of shale, which were mixed together for paving-brick and draintile, while the fire-proofing and inferior fire-brick were made from the impure fireclay. The annual value of the output was about $40,000, and the plant was valued at $30,000. The most serious objection to the plant was its long distance from a large market, so that freights must have largely absorbed the profits.

BILLINGS.

Springfield Fire and Paving Brick Co. The company was organized in 1887, with Springfield capital, for the manufacture of building and paving brick. The plant is located in Christian county two and one-half miles west of the town of Billings, on the St. Louis and San Francisco railroad. It is built near a pit of gray shale. The shale bed, already described, has two pits opened on it, one about 125 by 150 feet, and a smaller one about 40 by 50 feet. The company did not enjoy a prosperous career, and after a limited production shut down in 1892, since which time the machinery has been removed. The plant was equipped with a No. 7 Penfield stiff-mud machine, with a daily capacity of 20,000, and a 40 horse-power engine and boiler. The brick were

burned in three clamp kilns of 150,000 capacity which yielded only a small percentage of No. 1 pavers. Only a few pavers were made, the output being mainly building brick, which were shipped to Springfield, 22 miles distant.

ST. JOSEPH.

Halsey and Co. In 1887 this plant was built for the manufacture of paving and building brick. It is equipped with a Chambers stiff-mud auger machine of 30,000 daily capacity and is driven by a 60-horse-power engine and boiler. It has eight kilns six of which are down-draught. Both pavers and common brick are made, but mainly the former and the output has reached 4,000,000 a year. The same shale is used as at the St. Joseph Paving-brick yard.

St. Joseph Paving Brick Co. This plant was built in 1888, with a capital of $30,000. It is situated two miles south of the Union station at the foot of the river bluffs, and on the southern railway belt. It works the bed of shale already described as 65 feet in thickness. The plant is equipped with a Chambers stiff-mud auger machine of 40,000 daily capacity, one dry-pan, one 4-mesh screen and an 8-foot horizontal pug-mill. It is run by a 65-horsepower engine and boiler. The brick were formerly dried by air on the yard, but an iron-clad steam dryer with 30,000 daily capacity has since been erected. The brick are burned in five circular down-draught kilns, that are from 26 to 30 feet in diameter, one rectangular Eudaly down-draught kiln of 140,000 capacity, and three up-draught clamp kilns, of 225,000 capacity each. The output has reached 5,000,000 a year which is mainly pavers that have been used in St. Joseph, Omaha, Topeka, Kansas City and Sedalia.

King Hill Brick Co. This company works the same shale as the St. Joseph Paving Brick company and manufactures both paving and building brick. There is a stiff-mud Penfield auger machine of 40,000 capacity, with two boilers. The plant is equipped with two rectangular down-draught kilns of 75,000 and 150,000 capacity respectively, and three up-draught clamp kilns of 200,000 to 300,000 each. The annual output is about 5,000,000, which is mainly sold in St. Joseph.

KANSAS CITY.

Diamond Brick and Tile Co. The location of this plant is at Diamond station six miles southeast of Kansas City, on the Paola branch of the Missouri Pacific railroad and on the Kansas City, Osceola and Southern railroad. It was built in 1888, with a nominal capital of $75,000, for the manufacture of paving-brick, terra cotta and fire-proofing, with a capacity of 30,000 brick a day. The clay used is the shale bed 22 feet thick that outcrops in the bluff about 1,000 feet from the

A MODEL PAVING-BRICK PLANT; DIAMOND BRICK CO.

works, and which is worked by the room and entry system. The lower ten feet only is mined, by drifts or entries, that are 10 to 12 feet wide. On the failure of this company in 1891, from insufficient capital and poor management, the plant was remodelled and very much enlarged and is now equipped with a 40,000 capacity Chambers stiff-mud auger machine, two 9-foot Frost dry-pans, a fixed screen that is 8 by 2½ feet and set at an angle of 40 degrees, a 6-foot horizontal pug-mill, a 125 horse power Corliss engine, a 40-horse power slide valve engine, and two boilers. There is a steam dryer with four tunnels of three tracks each, giving a capacity of 66,000 brick a day, and six rectangular down-draught Eudaly kilns, three of which are of 100,000 and three of 200,-000 capacity. The output is exclusively paving-brick, and it is claimed that 85 per cent are No. 1 quality that sells for $10.00, free on board cars at the works, 10 per cent are No. 2 quality, that sell at $7.00 to $8.00, and 5 per cent are builders, that sell at $4.00 to $5.00 a 1,000. The output is mainly sold in Kansas City though shipments have been made to Springfield and Sedalia. It is a typical paving-brick plant and is shown in plate XXXI.

TARKIO.

Rankin and Wolfe Paving Brick Co. This plant, built in 1888, is on the Tarkio Valley branch of the Kansas City, St. Joseph and Council Bluffs railroad, near Tarkio, in Atchison county. It comprises one Penfield stiff mud machine of 40,000 capacity, one 9-foot Frost dry-pan and one horizontal pug-mill. It is driven by a 125-horse power engine and two boilers of 175-horse power. It is provided with two steam dryers of 40,000 daily capacity and two kilns, one, an up-draught of 500,000 capacity and the other a patent continuous kiln of 500,000 capacity, of home design. It is claimed that the fuel cost is only 35 cents a thousand bricks with the latter. The clay used is a shale from pits four miles south of Tarkio, which is described in another place.

MOBERLY.

Moberly Brick, Tile and Earthenware Co. This company was organized in 1889, with a capital of $25,000. The plant is located on the Wabash railroad, one mile east of Moberly, and works the shale bed already described that lies one mile south of the factory, with which it is connected by a narrow gauge railroad, on which is operated a 11-ton locomotive. The plant makes paving and building brick, having a 40,-000 daily capacity. It is equipped with a Frey-Sheckler stiff-mud augur machine for pavers and a four- and a three-mould Andrews dry-press for building brick, two 8-foot Frost dry-pans and a 6-foot horizontal pug-mill, while the power is furnished by a 100-horsepower engine and boiler. The brick were formerly dried on the yard, but in

1893 an eight-track Standard steam dryer was erected that is 90 feet long, with a capacity of 50,000 brick a day. The draught is produced by a large Sturtevant fan, which has proven very satisfactory in not cracking the brick. There are four rectangular, down-draught Eudaly kilns of 180,000 capacity each. The plant has a capacity of 10,000,000 brick per annum. The paving-brick have been largely used at Moberly, and have been shipped to Brookfield, Chillicothe, Hannibal, Sedalia and St. Louis.

Star Brick Co. This plant was erected in 1892, with a capital of $15,000. It is located one and one-half miles west of Moberly, on a spur from the main line of the Wabash railroad. The clay used is a soft, argillaceous shale that is dug from a bank 200 yards from the works and burns to a fine dark red color. The shale is crushed in a 9-foot dry-pan, screened through a 10-mesh inclined screen 10 by 4 feet and then fed to a 4-mould Boyd dry-press of 20,000 capacity. The plant is run by a 16 by 24-inch engine. The brick were formerly burned in three up-draught clamp kilns of 180,000 capacity each, but these have given way to Eudaly down-draught kilns. The product at present is about 1,000,000 building brick per annum, but the intention is to put in a mud machine and a dryer, and make paving-brick. One such attempt was made with the Ohio stiff-mud machine, for which a dryer was erected, but it did not prove successful so it was removed. The brick are mainly sold in and about Moberly and are of excellent quality.

KNOBNOSTER.

Knobnoster Mining and Manufacturing Co. The plant is located on the main line of the Missouri Pacific railroad about half a mile east of the Knobnoster station in Johnson county. It was built in 1890, with a capital of $12,000. It is equipped with a Little Wonder stiff-mud auger machine of 20,000 daily capacity, a Wallace tile machine, and a dry-pan. It is run by a 14 by 32-inch engine that is rated at 85-horse-power, and two 4 by 32 feet boilers. The brick are dried on the yard under sheds, and burned in three up-draught clamp kilns of 150,000 capacity and one rectangular 15 by 40 feet down-draught kiln of 100,000 capacity. This plant uses a shale and common clay obtained from a bank 1,000 feet east of the yard. Paving and building brick are made, which are shipped to Kansas City, Sedalia, Fort Scott, Topeka, and Wichita. The output reached 1,000,000 a year.

DEEPWATER.

Missouri Clay Co. This company was started in 1890 with a capital stock of $20,000. The plant is located on the Kansas City, Fort Scott and Memphis railroad, about one mile south of Deepwater, in Henry

county. The clay is obtained from an open pit 36 feet deep that lies 100 feet east of the factory. It is equipped with a Wassel steam press, which is a horizontal, double plunger that is similar to a sewerpipe press and has a 40-inch steam cylinder with a 36-inch stroke that operates two 20-inch clay plungers. It makes alternately four bars of clay at a time at each end of the clay cyclinders and is rated at a capacity of 5,000 brick an hour. For the present only one clay plunger is used, or is operating single acting. An 8-foot dry-pan crushes the clay through one-sixteenth inch holes, which without further screening, is pugged first in a 6-foot horizontal pug-mill and then repuged in an 8-foot pug-mill before going to the press. The brick are dried on floors heated by steam pipes, and burned in two rectangular down-draught kilns of 140,000 capacity each, and two up-draught clamp kilns of 100,000 each. The works are run by a 16 by 24-inch engine that is rated at 85 horsepower and one 5 by 18 boiler. The output, amounting to 5,000,000 a year, is paving and building brick, which are shipped throughout western Missouri and eastern Kansas. The company failed in 1891, from lack of capital but has since been operated with success, under a receiver.

BROWNINGTON.

Kansas City Vitrified Brick Co. The plant erected in 1891 is one and one-fourth miles west of Browningtou, Henry county, on a spur of the Kansas City, Osceola and Southern railroad. It is equipped with a Little Wonder stiff-mud auger machine of 18,000 capacity, which makes three bars of clay at a time. The clay is crushed in an 8-foot dry-pan with one-fourth inch grates, and without further screening goes to a 6-foot horizontal pug-mill. It is run by a 12 by 20-inch engine that is rated at 60 horse-power, and a 5 by 16-foot boiler. The brick are dried in a steam dryer of 34,000 capacity and require three to four days to dry (from imperfect design, rather than from a tender clay). The burning is carried on in three up-draught clamp kilns one of which is of 100,000 and two of 140,000 capacity each. The brick have been shipped largely to Springfield, for sewer purposes, and the output has been as high as 4,000,000 a year. The clay is obtained from a bank about a quarter of a mile west of the works.

RICH HILL.

Rich Hill Vitrified Brick Co. The plant was erected in 1891 with a capital of $20,000. It is located on the Joplin branch of the Missouri Pacific railroad, about half a mile north of Rich Hill, in Bates county. It is equipped with a Kell stiff-mud auger machine of 25,000 capacity, which makes three bars at a time. The clay is crushed in a 9-foot dry-

pan, then run through screens, and pugged in an 8-foot horizontal pug-mill. It is run by an 80-horse-power engine and a 80-horse-power boiler. The brick are air-dried and then burned in three up-draught clamp kilns of 115,000 capacity each. The product is vitrified brick, building brick and draintile. One million bricks a year have been made, and marketed in the immediate neighborhood. The clay is obtained from a bank 500 feet from the factory.

AKINSVILLE.

Columbian Press Brick Co. This plant was erected in 1892, with a capital of $10,000. It is located on the Versailles branch of the Missouri Pacific railroad, at Akinsville station in Morgan county. It is equipped with a Decatur stiff-mud auger machine (of 20,000 capacity), a 9-foot Frost dry-pan, a 12-foot, 8-mesh inclined screen, and an 8-foot horizontal pug-mill. It is run by a 13 by 18-inch engine, and an 80-horse-power boiler. It has two circular down-draught kilns of the Decatur pattern. The intention was to make paving-brick, stock-brick and draintile, but it was found that the clay would not work by the stiff-mud process, and the works shut down. The clay is obtained in open pits adjoining the plant.

Statistics of the Paving Brick Plants in Missouri.

Name.	Town.	County.	Began.	Machine.	Capacity of machine.	H. P. engines	No. boilers	No. kilns	Capacity of kilns	Dry by	Product.	Output, 1890	Output, 1891	Value, 1891	Value of product to 1892
Rankin and Wolfe	Tarkio	Atchison	1888	Penfield	40,000	125	2	2	1,000,000	Steam	Pavers, common	1,000,000	1,000,000	$8,000	$40,000
Rich Hill Vitrified B. & T. Co.	Rich Hill	Bates	1892	Chambers	25,000	80	1	3	115,000	Air	Pavers, com., tile	....	....	.....	10,000
Halsey & Co.	St. Joseph	Buchanan	1897	Penfield	30,000	60	1	8	250,000	"	Pavers, common	4,000,000	4,000,000	26,000	120,250
King Hill Brick & Mfg. Co.	"	"	1889	Chambers	40,000	80	2	5	925,000	"	" "	5,000,000	4,000,000	28,000	84,000
St. Joseph Paving Brick Co.	"	"	1888	"	35,000	65	1	9	365,000	Steam	Pavers	....	4,500,000	40,500	40,500
Springfield F. & Pav'g B. Co.	Billings	Christian	1887	Penfield	20,000	40	1	2	150,000	Air	Pavers, common	....	600,000	4,200	....
Kansas City Vitrified B Co.	Brow'ngton	Henry	1891	Little Wonder	18,000	60	1	3	240,000	Steam	"	....	4,000,000	30,000	30,000
Missouri Clay Co.	Deepwater	"	1890	Steam plung.	100,000	100	1	4	620,000	"	"	5,000,000	3,000,000	19,500	52,000
Diamond Brick & Tile Co.	Kansas City	Jackson	1888	Chambers	40,000	165	2	6	1,200,000	"	Pavers	2,500,000	5,000,000	45,000	45,000
Knobnoster Mining & Mfg. Co	Knobnoster	Johnson	1890	Little Wonder	20,000	80	2	4	236,000	Air	Pavers, common	300,000	1,300,000	9,100	11,200
Columbian Press Brick Co.	Akinsville	Morgan	1892	Decatur	20,000	85	1	2	140,000	"	Pavers, stock, tile	....	....	....	....
Moberly Brick, Til'g & E. Co	Moberly	Randolph	1889	Frey Sheckler	85,000	100	1	4	200,000	Steam	Pavers, common	3,500,000	3,500,000	24,500	70,000
Star Brick Co.	"	"	1892	Boyd press	20,000	40	1	5	180,000	....	"	....	....	....	7,500
Totals	....	....	....	....	....	1075	17	57	....	....	....	....	30,900,000	234,800	460,490

CHAPTER XV.

BUILDING-BRICK CLAYS AND INDUSTRY.

The common or building brick clays are very impure, sandy clays, and though they are the cheapest of all, the most important clay industry of Missouri is founded on them, involving a capital of about $3,500,000, and an annual consumption of this class of clay of about 1,300,000 tons valued at $260,000. They are the most widely distributed of all clays, and are present to a greater or less extent in every county in the state, while the large river counties contain exhaustless beds of the very finest kinds. Although they are always very impure, sand is their principal foreign constituent which is alway present to a large extent, in a greater or less degree of coarseness. They also usually contain considerable feldspar in a more or less weathered or partially decomposed condition, while a high percentage of iron is seldom absent. Occasionally they are also rich in calcite and dolomite ("lime"), especially in the glacial clays, when the color of the brick is seriously affected. While characteristically brownish yellow to brown in color, on account of the iron present, they occasionally have a blue or dark color, from organic matter, that makes the usual iron-derived brownish shade.

CHEMICAL PROPERTIES.

The fluxing impurities, or the iron, lime, magnesia and alkalies, usually range from 8.0 to 11.0 per cent, while the free or uncombined silica or sand ranges from 30.0 to 60.0 per cent. This leaves only 30.0 to 60.0 per cent for the kaolinite base, and in a great majority of the brick clays it varies between 35.0 and 45.0 per cent, the sand being the predominant constituent. They might therefore be looked upon as very argillaceous sands if only the major constituent were considered and if they did not owe their working properties to the clay base. It is the clay base that gives them their plasticity, and therefore the ability to be moulded, and it is also the clay base that after burning gives the brick, its great strength, hardness, and ability to withstand the weather. The role played by the sand is very important, as when very fine, it detracts but slightly from the plasticity, while it greatly

decreases the shrinkage in both drying and burning, and usually allows rapid drying without checking.

The ferruginous minerals give the color to the red brick, and when lime and magnesia are present in large amounts, they give cream to buff to saddened red colors. The alkalies and other fluxing impurities are of no great importance in brick clays, as the latter are not expected to be refractory, nor are they burned to a vitrified body. They therefore only limit the point to which the clay may be heated without vitrifying. On account of the usually silicious nature of the clays, and the consequent rapidity with which they reach the critical or viscous stage after vitrification begins, they are rarely adapted for paving-brick, sewerpipe or other applications in which a vitrified body is desired. For flower-pots, terra cotta or other earthenware, in which a porous body or red color is desired or is unobjectionable, they are well adapted. The usual range in chemical composition is as follows:

Range in Composition of Brick Clays.

Constituents.	Average per cent.	Minimum per cent.	Maximum per cent.
Silica, combined	15 0	12.0	30.0
Silica (sand)	55.0	20.0	60.0
Alumina	14.0	11 0	25.0
Water, combined	4.0	3.0	9.0
Water, moisture	2.0	0.0	6.0
Iron sesquioxide	4.0	2 5	8.0
Lime	1 5	0.5	7.0
Magnesia	1.0	0 3	8.0
Alkalies	3.5	2 0	7.0
Total	100 0		

PHYSICAL PROBERTIES.

In their physical properties the brick clays vary greatly in plasticity, as some of the very coarse, sandy clays are very lean, while the clays in which the sand is very fine are sometimes very plastic. In most cases they are moderately plastic, or can be readily worked as a soft mud but require careful handling to avoid cracking and ragging if worked as a stiff-mud. When the plasticity is expressed by the tensile strength scale, they range from 80 pounds to the square inch which is very low, to 300 pounds which is very high, and average about 150 pounds. The amount of water required to develop the maximum plasticity ranges from 15.0 to 20.0 per cent and averages about 18.0 per cent. The shrinkage from drying the stiff-mud varies from 4.0 to

18.0 per cent and averages about 5.0 per cent. The fire-shrinkage in burning the air-dried clay to incipient vitrification ranges from 2.0 to 6.0 per cent and averages 4.5 per cent. The total average shrinkage averages about 10.0 per cent.

The time required to dry brick clays, and subsequently burn them varies greatly in spite of the fact that they are usually very silicious. When the sand is very coarse they can usually be rapidly dried and burned without checking or cracking; but when the sand is very fine they often require the greatest care and slowness in drying to avoid cracking to pieces, and frequently the same care has to be exercised in burning. It is by no means uncommon for the clays, in which the sand is very fine, to crack very badly when dried from a stiff-mud, in the usual time, or 24 to 48 hours, yet when the clay is dried it will often stand rapid burning without checking. This anomalous behavior is probably due to the fact that the sand and clay particles are so very fine that the interstitial channels are so badly clogged as to almost prevent the escape of the moisture from the interior of the brick while the outside is comparatively dry. This therefore causes the brick to crack, from the contraction of the dry exterior upon the uncontracted wet interior. Such a brick can only be safely dried by allowing the exterior to dry so slowly (by shutting off the air or heat, or by covering with a damp cloth) that the moisture from the interior may have time to slowly pass through the pores to the exterior, and thus allow the whole brick to contract uniformly. When the clay is burned, the small amount of chemically combined water remaining is able to escape sufficiently rapidly through the pores which are so enlarged through expansion caused by the heat as to prevent checking. In the former case it is the escape of 15.0 to 20.0 per cent of moisture through very contracted pores, while in the latter case only 2 0 to 5.0 per cent is expelled and the pores are greatly enlarged by expansion. Where clays are so fine-grained as to require extreme slowness in drying to avoid checking they can be greatly assisted by copious additions of clean, coarse sand, ashes, coke dust or dry sawdust. The coke and sawdust have the disadvantage of leaving the brick more or less porous, and are liable to injure the color, so that they are only desirable in the poorer grades of brick. When this method of reducing the shrinkage and hastening the drying by the use of "grog" is not permissible, and it always affects the strength of the brick unfavorably, the brick may be dried in a reasonable time by the use of salt in the water with which the clay is tempered, which prevents the rapid drying of the exterior. The

glacial clays in particular are liable to have this trouble and occasionally strong seams occur in banks of the loess and the residual clays.

The question of color in red building brick depends on:

(1) The presence of sufficient quantity of iron;

(2) The absence of notable quantities of lime and magnesia;

(3) The temperature at which they are burned; and

(4) The character of the fire, whether oxidizing or reducing.

The amount of iron should exceed 3.0 per cent and preferably 4.0 per cent but no improvement in color is noticeable after the amount exceeds 5.0 per cent. The lime and magnesia, if present in large amounts, bleach or destroy the color of the iron by giving the burnt clay a yellowish to cream color, no matter how much iron may be present. This is attributed to the formation if double silicates of lime and iron (similar to the mineral zoisite or lime epidote) which are nearly colorless. The amount of lime and magnesia that will injure the red color of a brick clay is about 5.0 per cent, when it begins to "sadden" in color. Above this it becomes more noticeable, until at about 10.0 per cent it is no longer red, but has a yellowish cast, and at 15.0 per cent or higher, it becomes a deep to pale cream.

The changes in color produced by temperature are extremely important, and result in that extensive series in the brick trade that runs from salmon through various shades to extreme dark red. On heating a brick clay it turns to a dull light salmon color at a red heat, or from 1,000° to 1,200° F.; at a slightly higher temperature, or about 1,300° to 1,400°, it becomes a deep salmon, at a bright red heat or 1,500° to 1,600°, it becomes light red, or at 1,800° to 1,900° a deep red. At a bright cherry heat, or about 2,000°, to 2,200°, it becomes a very dark red, and at a slightly higher heat or 2,300° it usually fuses and turns black.

Incipient vitrification usually takes place, at least in the loess clays at about 2,000° F., and complete vitrification at about 2,200°, while viscous vitrification, when the clay fails to retain its shape, usually occurs at 2,300°. On account of the limited range of only about 200° in the vitrifying stage these clays are very poorly adapted for paving-brick, as it is impossible to successfully control the contents of the kiln within such a narrow range of temperature. Consequently only a small percentage would be properly burned, the rest being underburned in the upper portion and overburned in the lower portion of the up-draught type of kiln. In addition to this, is difficulty of burning a large percentage to a proper degree of hardness for the loess clays, even when properly vitrified, do not usually have the toughness that is requisite in a paving-brick.

If the brick are very slowly heated in the preliminary or water-smoking stage, the color is deeper and richer than if this is hurried, from the more thorough oxidation of the iron to the red anhydrous sesquioxide, and when color is an important object, the burning should be carried on slowly if the finest shades are desired. In burning brick it is necessary to have an excess of air in order to oxidize the iron, if the brightest colors are desired. If a very smoky fire is carried, or if there is an insufficient amount of air, there will be an imperfect oxidation of the iron with the consequent darkening of the color. When very dark brick are desired they are readily secured by burning the kiln with a very smoky flame, with the air supply cut off as much as possible.

The specific gravity of the brick clays varies from 1.65 to 2.20, and averages about 2.00. They are among the lightest of clays, which is due to the fact that they have but little or no overlying matter to consolidate them, as is usually the case with the shales and fireclays.

CLASSIFICATION AND OCCURRENCE OF BRICK CLAYS.

The brick clays of Missouri can be divided into four classes:

(1) Loess clays,

(2) Glacial clays,

(3) Residual clays, and

(4) Alluvial clays, or present stream deposits.

These four classes of clays differ sufficiently in their general character and mode of occurrence to deserve separate discussion. They vary greatly in their economic importance, the loess clays being by far the most valuable, while the residual and alluvial clays are as yet of slight economic importance. The loess clays are invariably confined to the immediate neighborhood of the larger streams, especially of the Missouri and Mississippi. The glacial clays are confined to the country north of the Missouri river, or approximately the north half of the state. The residual clays are found south of the Missouri river or approximately the south half of the state, while the alluvial clays are found along the bottoms of the present streams, and are secondary derivatives of the preceding classes.

THE LOESS CLAYS.

The loess clays are the most important brick-making clays in Mis-Missouri on account of (1) the high grade of brick made therefrom; (2) the ease with which they can be worked; (3) the general uniformity of the deposits; (4) the great thickness of the deposits; and (5) the extent of the deposits.

The loess clays are those very characteristic yellow or brown oxidized clays that are found in the immediate vicinity of the rivers, more especially of the Missouri and Mississippi. They have the characteristic feature of being usually non-stratified, and exhibit a columnar structure in banks, that is very striking and is well illustrated in plate XXXII. This columnar structure is almost invariably present, and is one of the most characteristic features of the loess. In its normal character the loess is a very sandy clay, in which the grains of sand are very fine and uniformly disseminated through the clay. It is always free from pebbles, gravel and bowlders save at the base where a thin bed of gravel makes its appearance as it merges into the drift. The loess is sometimes so very sandy as to become a loam or moulding sand, when it is usually too weak and lacking in plasticity to satisfactorily answer for brick, though there is sufficient clayey matter mixed with the sand to answer for moulding in foundry practice. This very sandy character of the loess is usually confined to the immediate vicinity of the river banks and rapidly changes to a less sandy clay away from the river; it is always local in character, and does not extend far along the river bank. Farther from the river the loess generally becomes finer in grain and frequently passes into a strong, tough clay. This strong clay is often found overlying the softer, sandy clay, with a fairly strong line of demarkation.

In the northern half of the state the loess is always found overlying the drift and glacial clays, between which there is usually no line of demarkation. In other cases there is a well defined separation between the overlying loess and the underlying drift, but more frequently they merge into one another within a limited distance.

The loess varies greatly in thickness, being as great as 200 feet at the Iowa line in the bluffs of the Missouri river. In the neighborhood of St. Joseph the hills show 100 to 175 feet, as seen in plate XXXIII; while 75 to 100 feet are frequently to be observed along the lower portion of the Missouri river. The loess is not so thick along the Mississippi river, rarely attaining a thickness of 75 feet, and seldom exceeding 50 feet, especially towards the southern portion of the state where 20 feet is more common. The loess always thins out on either side of the streams and usually completely disappears within a distance of three to ten miles. Rarely is it found at as great a distance as fifteen miles. The general tendency is for the loess to increase in thickness towards the north and especially on the Missouri river.

To the practical brickmaker, the coarse, sandy loess that occurs along the edge of the river is admirably adapted for hard or soft-mud brick, whereas it is unsatisfactory for the dry-press process, from lack

JOINTAGE OF THE LOESS (BRICK CLAY) AT KANSAS CITY.

of sufficient cohesion, and from the excessive wear of the dies. Farther from the river the clay is stronger, and much better adapted for the dry-press process, and when very strong it is usually impossible to work it by the mud-process (by hand or machine) as it shrinks and cracks so badly in drying, unless heavily tempered with sand, "grog," or other non-shrinking material. Usually it contains sufficient iron to give an excellent red color to the brick, if properly burned, and if handled with sufficient care it makes a superior quality of face or stock brick.

OCCURRENCE OF THE LOESS.

The occurrence of the loess can only be treated broadly, from the fact that it fringes, with slight interruptions resulting from erosion, all the large rivers in the northern half of the state, as they are in the alluvial plain stage of development. In the southern half of the state, where most of the rivers rise in the elevated area known as the Ozark uplift, they are in the torrent stage of development, and consequently have no broad alluvial bottoms to overflow. The loess is consequently usually absent from these southern rivers. The Mississippi is an exception, as heading in the distant north it flows through a wide valley of its own making, while it is fringed with deposits of the loess that extend from three to six miles from the river. With this important exception, the occurrence of the loess is confined to the central and northern portions of the state. The loess is preeminently developed along the Missouri river, and presents an almost unbroken sheet from the Iowa line to its junction with the Mississippi. It has a maximum thickness of 200 feet, usually ranging from 50 to 125 feet in thickness. When it is extremely thick it is sandy, and not as desirable for brick as when thinner and stronger. There is scarcely a gap in the continuity of the loess from the Iowa line to St. Charles, a distance that approximates 500 miles, as measured along the river.

The Mississippi fringe of the loess ranges from 50 to 100 feet in thickness in the northern portion of the state, and from 20 to 50 feet in the southern portion (see plate XXXIV.). The loess of the lower portion of the Mississippi is usually of excellent quality for brick-making, as it is seldom coarse and sandy.

The loess fringes the other large streams in the central and northern portions of the state, but is rarely as thick, and rarely occurs in such wide fringes, as along the Missouri or Mississippi rivers.

TESTS OF THE LOESS CLAYS.

The following analyses and tests of the loess were made on samples that were collected over a distance of 250 miles, and they show an unexpected uniformity in composition and physical character that strongly emphasizes the hypothesis that it all had essentially a common origin. The Kansas City, Boonville, and Jefferson City samples are from the south bank of the Missouri river, while the Hannibal, St. Louis, and Benton samples are from the west bank of the Mississippi.

Physical Tests of Loess Clays.

Locality.	Plasticity.	Size of grain	Tensile str'gth		Per cent water in paste	Shrinkage.							Temperature of vitrification. (F.)		
						In drying.			In burning			Total			
			Average	Maximum		No. of samples	Shrinkage	Speed	No. of samples	Shrinkage	Speed		Incipient	Complete	Viscous
Kansas City....	Lean	F	151	175	18.4	14	5.1	S	1	5.7	R	10.8	2,000	2,200	2,300
Boonville.......	Very lean ...	F-C	97	112	19.3	15	4.7	M-R	1	5 1	R	9.8	2,000	2,200	2,300
Jefferson City..	Lean	F-C	131	149	17.2	16	5.7	S	1	4.8	R	10.0	2,000	2,200	2,300
Hannibal.......	Lean	F	126	148	18.4	14	4.5	M-R	1	5.9	M-R	10.4	2,000	2,200	......
St. Louis	Slightly lean	C	173	205	17.1	16	5.3	S	1	5.5	R	10.8	1,800	2,000	2,100
Benton	Rather lean.	C	169	190	19.2	14	3.3	M-R	2	3.4	M-R	8.7	1,800	2,000	2,100

Analyses of Missouri Loess Clays.

Locality.	Silica	Alumina	Comb'd water	Iron sesqui-oxide	Lime	Magnesia	Alkalies	Total	Total fluxers	Specific gravity
Kansas City	72.00	11.97	6.42	3.51	1.80	1.35	3.25	100.80	10.11	2.17
Boonville	71.11	11.62	6.71	3.90	2.37	1.47	3.14	100 32	10 88	2.20
Jefferson City..............	74.39	12.03	3.17	4.06	1.50	1.53	3.01	99.68	10.09	2.09
Hannibal.............	73.80	13.19	5.26	3.43	0 86	0.68	2.94	100.16	7.91	2.17
St. Louis................................	73.92	11.65	3.08	4.74	1.43	0.60	3.13	100.73	9.90	1.93

As the samples average very closely to 73 per cent of silica, with only about 12 per cent of alumina, it shows the presence of about 55 per cent of free silica or sand, thus strongly indicating their alluvial origin. In the settling basins of the St. Louis water works, where the muddy water of the Mississippi is allowed to rest from 24 to 48 hours

BLUFFS OF LOESS, OR BRICK CLAY, ON THE MISSOURI RIVER AT ST. JOSEPH.

before use, the sediment is mainly sand, of apparently uniform texture, and contains a higher percentage of total silica than the average loess. This 24 to 48 hours settling does not remove all the sediment, as the water is still slightly turbid, with extremely fine suspended matter that glistens in reflected light, indicating a crystalline structure. A sample of this very fine suspended matter that had failed to settle in the settling basins was obtained by allowing the water to stand in a bottle for 3 to 6 days, when it became perfectly clear, and the impalpably fine material gave the following results of analysis, showing that it is much less silicious or contains only about 25 per cent of sand, and much more alumina than the average loess, as would be expected from its extreme fineness; it very closely resembles it in the fluxing constituents.

Analysis of Settlings from St. Louis Water.

	Per cent.
Silica	51.68
Alumina	23.65
Combined water	8.75
Moisture	5.14
Iron sesquioxide	6.63
Lime	1.40
Magnesia	0 20
Alkalies	2.23
Total	99.68

The total amount of fluxing impurities was 10.46 per cent. Incipient vitrification occurred at 1,800° F., complete at 2,000°, and viscous above 2,100°.

The loess samples were all collected within a distance of one mile from the river bank, except at St. Louis and Benton. The former of these was collected about three miles (King's highway) from the river at a point at which the loess extends as much as ten miles from the present bank, while the Benton sample occurs on the flank of an old island of the Mississippi, which to-day is several miles inland from the meandering of the river to the eastern side of its wide valley.

GLACIAL CLAYS.

The glacial clays cover almost the entire northern half of the state, from the Iowa line to approximately the north bank of the Missouri river. The glacial clays vary greatly in physical properties and chemical characters. They are generally unassorted and liable to vary greatly in character and quantity. The deposits rarely exceeds 50 feet in thickness. The glacial clays of Missouri are usually predominatingly yellow to brown in color, and are intermixed with varying amounts of gray or light colored clay and more or less sand and gravel. Large bowlders are usually absent, except near the Iowa line and the clay is

as a rule not stratified. The blue clay that occurs so extensively at or near the base of the drift in the north is seldom found in Missouri. Sand in pockets, streaks and beds occurs with the drift clays in a very irregular manner. On account of the finely comminuted condition of much of the material, the glacial clays are for the most part very strong or extremely plastic, which makes it almost impossible to dry them without cracking. They are very often contaminated with concretions of carbonate of lime as small irregular to rounded gray nodules. Occasionally the glacial clays form pockets or bodies of considerable size and uniformity, that are almost free from sand, pebbles and concretions, and which make a fair brick clay if worked by the dry-press process. Occasionally bodies of rather pure clay of a good gray color occur that are suitable for stoneware, draintile, flower pots, and similar goods. In most cases, however, the very strong or plastic nature of the glacial clays and their variation in iron and lime make them so variable in color, unless very carefully mixed when tempered, that they are unsatisfactory for building brick. When they have been reassorted by washing, as on the flanks of the hills, by which the very fine clay is removed, they are more tractable and form the source of supply of many local hand yards in the northern part of the state. This reassorted material is not usually very thick, ranging from one to six feet, and generally requires considerable care on the drying yard often necessitating the use of salt to ensure safe, slow drying.

The color of the burned brick is sometimes a good red, but is more frequently saddened by the presence of considerable lime (as carbonate) and occasionally it is due to an insufficiency of iron. If the brick can be safely dried they usually give much less trouble in burning and make a strong building brick that successfully resists the action of the weather. Sometimes the percentage of lime is so high as to result in a buff or yellowish brick similar to the famous Milwaukee brick.

No large brickyards or other clay industries have been founded on the glacial clays in this state and with such abundant deposits of better material as the loess, it would be unwise to invest on such a variable class of deposits. Local exceptions may occur that may justify a large plant; but before erection the clay bank should be thoroughly tested by a large number of pits or bore holes, to verify the thickness, extent and quality of the clay that it is proposed to use.

LOESS-CAPPED BLUFFS ON THE MISSISSIPPI RIVER AT ST. LOUIS.

RESIDUAL CLAYS.

The residual clays are the yellow to brown and red clays found overlying the limestones and other rocks in place. They have been derived from the decay and dissolution of the rocks on which they rest. They have not been transported or carried long distances from their point or origin, as is the case with the loess, glacial and alluvial clays. They vary considerably in character, according to the rock from which they have been derived. In this state they have been largely derived from the limestones and to a much less extent from the shales. In the northern half of Missouri they are usually buried or hidden from view under the heavy mantle of drift or loess. In the southern half of the state, except in the immediate neighborhood of the large rivers, they are the usual surface clays and vary from one to ten feet in thickness.

The limestone-derived clay varies from yellow to brown or red in color, is very strong and tenaceous or excessively plastic, and in consequence it can seldom be used, as it cracks badly in drying and burning. While it is usually from 2 to 5 feet in thickness there is a deposit two miles north of Fredericktown, in Madison county, that is as great as 90 feet in thickness, as shown in various test pits on the Cantwell property. The thickness of the residual clays is largely a question of topography, for if the slope is so steep as to enable the clay to wash away faster than the rock decays, little or no clay results, while if the relief is very flat so that there is little or no erosion, the clay will accumulate faster than it washes away and very thick bodies result.

The plastic clays resulting from the weathering of shale, though strictly a residual type of clays, have been alluded to under shales, into which they soon merge within a few feet from the surface; and as they partake of the same character of shale when the latter is ground, they are adapted to the same purposes. The exceptionally pure limestone-derived clays, that have produced the Missouri kaolins, have also been described, though in this state they are often true residual clays.

ALLUVIAL CLAYS.

The alluvial clays are those recent deposits of the present streams that are found in the flood-plains. They are the result of the washing or erosion and subsequent deposition of the loess, or glacial, or residual clays that occur in the drainage basin of the streams in which they are found. They consequently differ greatly in character, but this arises more from the nature of the stream, and the relative position they bear to the stream, rather than to their primary source. If the stream is small and rapid, the clay is sandy and course in character and occurs

as a long, narrow fringe along the stream without much thickness. If the stream is larger and less rapid, and especial if near grade, the clay is less sandy, and usually has a greater thickness. If the stream is in its flood-plain stage, especially if large or covers wide basins when it goes out of its banks during the spring floods, the clay is fine and covers a wide space, and has considerable thickness. In the latter class of alluvial clays the clay would be coarser and more sandy near the banks of the stream, and fine and less silicious further away. This relative difference in the clay, being less sandy and finer the greater the distance from the river bank, applies throughout the entire course of the stream. If the stream is young, or follows a recent drainage line, the alluvial clays are alway very thin, while if the stream is an old one, especially if large, the clay is thick and covers a wide area. On account of this variation, from the very fine plastic to very coarse sandy lean condition, the clays vary greatly in value for brick-making. In one case a clay is identical with the leaner type of the loess clays and hence admirably adapted to all the processes of brick-making. On the other hand it is the gumbo clay, which though admirably adapted for burnt ballast is a signal failure for brick-making, on account of the excessive strength and plasticity. When suitable for brick-making, or neither too fine or too coarse, the deposits are not usually as extensive as the loess, though they are often large enough to justify the erection of a large brickyard. When too fine, or too strong, or so excessively plastic as to crack to pieces in drying and burning, they are eminently suited for burnt ballast. Chemically the alluvial clays vary from the silicious loess on one side to the more aluminous gumbo clays on the other hand.

The alluvial clays have been extensively used in this state in the smaller cities and towns, but there is considerable trouble from seepage and spring over-flows from streams along which they occur.

EXTENT OF THE BUILDING-BRICK INDUSTRY.

In the manufacture of brick, Missouri is one of the leading states in the country, as it not only produces all its own brick, but ships extensively to the neighboring states, while its ornamental and stock bricks go as far as St. Paul on the north, New York in the east, New Orleans on the south and the Pacific slope on the west. The St. Louis brick have a national reputation that they well deserve, on account of their excellence in quality and beauty in color.

The St. Louis district with an annual capacity of 3,000,000,000 brick is not only one of the largest in the country, but it contains the largest brick-making company in the world. Before this company established

branch yards at all the principal brick markets it shipped large quantities of stock and ornamental brick through the country. This extensive development of the brick industry is primarily due to the existence of very large quantities of clay of exceptional quality or the loess deposits, that fringe the banks of the Mississippi, the Missouri and other large rivers, which have a thickness of 15 to 20 feet. The dry clay process, or the latest improvement in brick-making, was also first successfully established in this state and this is now the method by which most of the brick are made. St. Louis is by far the most important manufacturing center, and produced about 240,000,000 a year, which are almost entirely made by the dry-press process, except in a few small hand-yards and the loess is exclusively used.

Kansas City usually makes about 50,000,000 a year, which are made by both the dry-press and soft-mud processes, from the loess.

St. Joseph makes about 20,000,000 a year, which are made partly by the dry-press, and partly by the soft-mud process from the loess.,

These are the most important centers though very numerous plants are scattered throughout the state, as is shown in the statistical table at the end of the chapter. The smaller plants use the loess clays, when situated at or near the large rivers, or the glacial clays, when away from the large rivers in the northern part of the state, and the residual clays in the southern part of the state. The dry clay process is largely used at the smaller plants when the demand justifies it, and the soft-mud process is mainly used at the very small or hand yards. The total production of Missouri for the year 1891, from 358 yards, was 433,128,000 brick, valued at $3,496,966, the estimated capital being $3,500,000. Considerable difficulty was experienced in getting returns from the very small country yards and estimates had frequently to be made in consequence, but these do not materially affect the following summary, by counties, the details of which are given at the close of this chapter:

Table of Output of Brick in Missouri for 1891.

County.	No. yards.	No. kilns.	Output.	Value.
Adair	5	5	2,100,000	$13,200
Andrew	1	1	300,000	2,100
Atchison	6	7	1,550,000	10,100
Audrain	3	4	2,100,000	14,700
Barry	2	4	375,000	2,625
Barton	1	1	....	....
Bates	2	7	1,950,000	13,650
Bollinger	1	1	100,000	700

OUTPUT OF BRICK IN MISSOURI FOR 1891—Continued.

County.	No. yards.	No. kilns.	Output.	Value.
Boone	3	5	1,700,000	$10,700
Buchanan	15	48	21,100,000	131,575
Butler	1	2	450,000	3,150
Caldwell	3	3	480,000	3,210
Callaway	5	13	3,500,000	21,100
Cape Girardeau	4	8	2,250,000	11,500
Carroll	8	12	2,750,000	17,050
Cass	3	8	1,875,000	11,825
Cedar	1	1	100,000	700
Chariton	3	9	1,900,000	12,900
Clark	4	8	1,650,000	9,550
Clay	2	7	3,000,000	19,000
Clinton	2	2	300,000	2,100
Cole	2	5	1,800,000	11,600
Cooper	2	4	800,000	4,800
Daviess	4	7	900,000	5 500
Dallas	1	1	340,000	1,700
Dent	1	2	....	....
Dunklin	1	1	250,000	2,250
Franklin	5	9	1,405,000	8,530
Gasconade	2	4	1,000,000	7,000
Gentry	5	11	1,706,000	12,292
Greene	7	14	3,700,000	22,325
Grundy	6	7	2,600,000	18,200
Harrison	1	1	200,000	1,400
Henry	7	16	2,200,000	14,550
Hickory	1	2	....	....
Holt	5	6	1,680,000	13,840
Howell	1	2	300,000	1,750
Howard	4	6	1,200,000	8,400
Jackson	23	86	54,900,000	444,180
Jasper	5	11	5,100,000	32,900
Jefferson	3	5	720,000	5,040
Johnson	1	2	500,000	3,500
Knox	1	2	500,000	3,000
Laclede	1	2	740,000	5,000
Lafayette	10	19	9,720,000	29,680
Lawrence	6	10	2,777,000	16,287
Lewis	1	1	200,000	1,200
Lincoln	3	3	560,000	3,920
Linn	9	15	3,100,000	20,100

OUTPUT OF BRICK IN MISSOURI FOR 1891—Continued.

County.	No. yards.	No. kilns.	Output.	Value.
Livingston	3	4	2,000,000	$13,500
Macon	6	8	1,960,000	12,400
Madison	1	1	200,000	1,600
Marion	3	6	1,675,000	11,000
Mercer	6	9	1,100,000	7,500
Mississippi	1	2	400,000	2,800
Moniteau	2	2	300,000	2,100
Monroe	3	3	450,000	3,300
Morgan	2	2	120,000	800
Montgomery	2	2	400,000	2,800
Newton	2	2	400,000	2,800
Nodaway	10	20	3,100,000	21,700
Oregon	1	1	200,000	1,000
Osage	1	1	....	....
Perry	8	9	1,010,000	6,260
Pettis	1	2	500,000	3,500
Phelps	1	1	200,000	1,400
Pike	6	11	2,280,000	14,600
Polk	2	5	450,000	2,250
Putnam	2	4	1,000,000	7,000
Ralls	2	3	300,000	2,100
Randolph	2	2	800,000	5,600
Ray	1	2	500,000	3,500
Saline	7	12	1,525,000	10,325
Scotland	5	6	800,000	5,500
Scott	1	1	100,000	700
Schuyler	5	6	1,155,000	10,625
Shelby	2	2	500,000	3,400
Stoddard	1	1	400,000	2,800
St. Charles	6	11	5,340,000	36,090
St. Francois	3	3	750,000	5,250
Ste. Genevieve	2	3	200,000	1,400
St. Louis	11	18	5,275,000	35,800
St. Louis city	39	195	244,745,000	2,227,647
Stone	1	1	....	....
Sullivan	6	6	800,000	5,600
Texas	2	2	200,000	1,400
Vernon	2	5	2,600,000	17,600
Warren	2	3	340,000	2,040
Worth	2	2	200,000	1,400
Grand total	358	794	433,128,000	$3,496,966

Summary for 1891.

Locality.	No. yards.	No. kilns.	Output.	Value of output.	Per cent.
St. Louis city	39	195	244,745,000	$2,227,647	64.0
St. Joseph	13	44	20,100,000	124,575	3 0
Kansas City	17	75	50,100,000	414,000	12.0
Remainder of the state	289	480	117,983,000	730,744	21.0
Grand total	358	794	433,126,000	$3,496,966	100 0

MANUFACTURE OF BUILDING BRICK.

In the manufacture of building brick four different processes are employed in moulding the clay, preparatory to burning:

(1) Dry-press,

(2) Semi-dry press,

(3) Stiff-mud, and

(4) Soft-mud.

Each of these methods has its special advantages and the decision as to which one to employ depends on, first, the character of the clay; second, the quality of the brick required; third, the size of the plant; and fourth, the capital available.

If the clay is suitable, with competent management and a properly equipped plant, there is not a marked difference in the cost of manufacture between these different processes where common brick is desired; and the selection of the process depends on one or more of the above conditions. A few clays can be worked by any of the four methods, but most clays cannot be.

The dry and semi-dry methods are suitable for a larger variety of clays than the mud methods. They are adapted to the very fat aluminous clays, as well as the most silicious, if not too coarsely sandy. They give a strong brick if well burned, provided the clay is not too sandy, and are especially favorable for perfect faces, edges and uniformity in size, and are therefore very desirable for face, ornamental, Roman and enamel brick. It is necessary however to store the clay for some time before use, which involves extra capital, handling, and extensive storing sheds. They require a more extensive plant for a given output than the mud processes and the presses are expensive and complicated, while they have only a moderate capacity (plate XXXV). If the brick are not completely burned they do not stand the action of frost, which readily disintegrates them. They need a much longer time in burning as they require very slow heating and water-smoking on account of their closeness and density. They have the

great advantage of not necessitating dryers, as they can be set direct from the machine into the kiln, with a consequent saving in labor and plant.

For the stiff-mud process the clay should be quite plastic and possess the property of drying within a reasonable time without checking, a feature that many plastic clays lack. This prevents the employment of very silicious clay in this process, while very strong, or aluminous clays, give trouble from excessive plasticity with consequent excessive laminations, besides being usually very difficult to dry. The clay can be used direct from the bank and the machinery is simple and capable of very large outputs with a moderate investment of capital. The brick are not as perfect in shape nor as uniform in size as those made by the dry or semi-dry press methods, and they are only desirable as common or backing brick. If repressed, however, they are suitable for stock or face-brick. They require the use of either drying yards or artificial dryers before being set in kilns.

The soft-mud process is adapted to very silicious clays that cannot be worked in any other way, as well as to any plastic clay that can be dried without cracking. The clay is used direct from the bank, and the machinery is extremely simple and inexpensive, especially when the hand process is used. The brick are very light, and are not as strong as those made by other methods, yet the clay particles are so well bonded that the underburned or salmon brick usually successfully resist frost action, which is not true of similar brick made by the other processes. The brick are liable to be imperfect as regards their faces and edges and are not uniform in size, while their color is usually ruined by the excessive amount of sand employed to prevent sticking in the moulds. When water is employed for the latter object, instead of sand, and the brick are repressed before perfectly dry they can be obtained of reasonable uniformity, and can be burned to a good color, and a stock brick made if desired. These generalizations as to the processes most favorable for a given clay are only true in a broad sense, as clays are so individual in character and differ so greatly in physical properties as to result in many exceptions. Thus, some of the very silicious clays have the sand in such a fine state of division as to be very plastic, while some highly aluminous clays have the clay particles in such a coarse condition as to be only moderately plastic. The only safe rule in examining a new clay is to make a complete set of physical tests, and when the investment of a plant depends on the decision, the laboratory tests should always be verified by actually making several hundred brick on machines that the tests indicate are most favorable for the given clay.

CLASSIFICATION OF BRICK.

The brick trade makes the following classification of the different grades of building brick:

(1) Common or backing brick.

(2) Stock or face-brick.

(3) Roman brick.

(4) Ornamental brick.

(5) Enamel brick.

Common Brick. Backing or common building brick are those which are used for all building purposes except fine fronts or facings. They are graded by the trade into: Salmon brick, light red, medium red, dark red, hard dark, straight hard and rough hard.

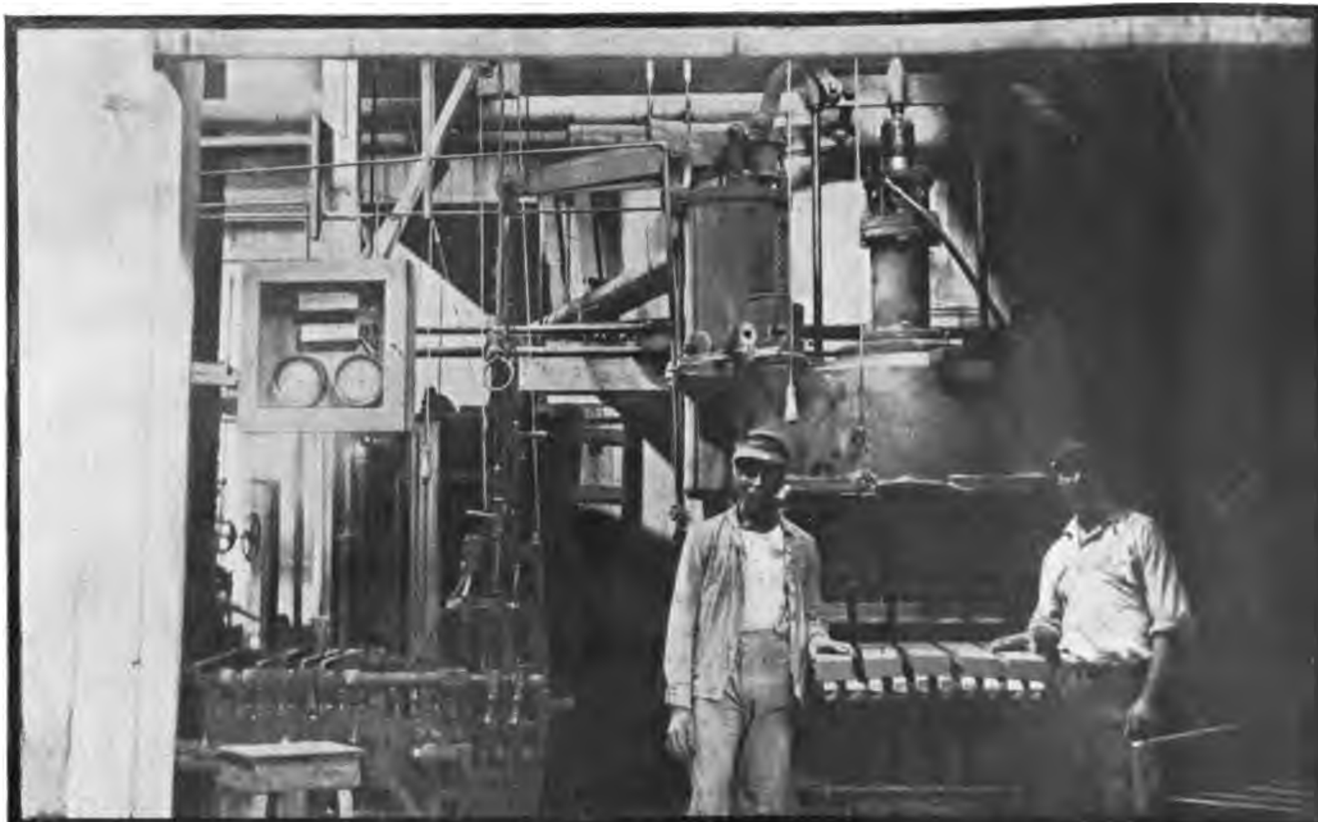
The salmon brick are the soft, underburned, salmon-colored brick rom the top of an up-draught kiln, or the bottom of a down-draught kiln. They are the cheapest grade of brick on the market and are used for backing and inside work, or where not exposed to the weather for to great pressure.

The light to dark red are strong, well-burned brick that are perfect in shape, uniform in color and are the favorite colors for fronts. They have been burned hard enough to stand the heaviest pressures and being the most attractive for outside or exposed work command the highest prices.

The "dark hard" are very strong, perfectly-shaped brick, but as the color is not uniform, they leaving a dark streak along the edges, they are not desired for fronts on account of their dark sombre shade.

The straight hard brick are perfect in shape, are very strong and are well adapted for sidewalks, sewers, and bridge-piers, where there is excessive wear or weight, but they are too streaked and lacking in uniformity in color to make a good appearance. The rough hard brick are from around the "eyes" of an up-draught kiln or the top of a down-draught kiln and are more or less warped and irregular in shape. They are only slightly porous, very strong, but badly discolored by fire. They are very desirable for foundations, sewers and backing.

Common brick can be made by any of the brick-making processes but the sizes differ somewhat, and they vary in different parts of the country. The size of a common press-brick in the St. Louis market is $8\frac{3}{8}$ by $4\frac{1}{4}$ by $2\frac{1}{4}$ inches. This is for a standard red brick. If the brick is underburned, or salmon colored, it is about one-eighth inch larger while if overburned, as a hard or straight hard brick, it is about one-eighth inch shorter, these differences in size being due to the shrinkage in burning at different temperatures.



HYDRAULIC PRESS-BRICK MACHINE.

The usual prices of common brick a thousand in the St. Louis market at the kiln, are about as given below. It is the custom, however, to sell building brick delivered at the works or building, which costs from 50 cents to $2.00 more a thousand, according to length of haul, the usual 2-horse brick-wagon holding 1,000 brick.

Backing Brick—	
Salmon	$3.00 to $4 00
Ordinary	4.00 to 5.00
Rough hard	4.00 to 5.00
Straight hard	5.50 to 6.50
Front Brick—	
Light red	6.50 to 7.50
Medium red	8 00 to 9 00
Hard red	8 00 to 9.00
Dark red	8 50 to 9.50

Stock Brick are simply those more carefully made, being perfect in shape and edges, while they are very carefully sorted as to shade of color. They are made from the same clay as the common brick, but have been made and handled with much greater care and sorted in the kiln to a close graduation of color, so that they present a beautifully uniform appearance. They are graded in color by numbers as follows, when a red burning clay is employed:

0 to 1, salmon.

2 to 3, light red.

4 to 5, medium red.

8 to 9, hard, dark red.

9 to 12, streaked dark red.

Of these, numbers 3 to 7 are the favorite colors and in greatest demand, and consequently highest in price. The stock brick command from two to four times the price of common brick, or for $12.00 to $20.00 a thousand. When fireclay, potters' clay, or other buff to cream or variegated clays are employed instead of a red-burning clay, a different system of numbering is employed to distinguish the different colors and shades, which vary with each maker. The buff, mottled, and variegated brick have been very popular in recent years, and have commanded very high prices, or as great as $40.00 a thousand. Stock brick are usually made in Missouri by the dry-press process, and occasionally by repressing soft mud brick, as at Philadelphia. They should always have at least one perfect face that is free from kiln marks, fire-flashing and other defects in color and shape. The size of a No. 5, or red stock brick, in the St. Louis market is 8⅜ by 4⅛ by 2⅝ inches. Stock brick are made one-eighth inch thicker than common brick, on account of the thinness of the mortar or close joint with

which they are laid, thus allowing the face or front brick to lay and band properly with the thinner backing of common brick, which have thicker mortar joints.

Roman Brick are a special size of front or face brick that have recently become very popular. As the name indicates the size is taken from the ancient Roman brick, which were very long and thin, as compared with the standard size. The size made by the Hydraulic Press Brick Co., of St. Louis, one of the largest manufacturers of this class of brick in the United States, is as follows: 12 by 4 by 1 11-16 inches. It makes a finer appearance, if well laid, than the usual sized brick, provided it is in harmony with the architectural design. It is a much easier brick to burn, on account of the thinness. It is made up in all colors, though the buffs are the most popular at present. It is usually made by the dry-press or the soft-mud and repress processes.

Ornamental Brick is the name given to the various shapes and sizes that are made for decorative and architectural effects. They are used for trimmings, cornices, mouldings and similar purposes. The varieties that are possible are infinite, and the stock carried by large manufacturers runs up into the hundreds. They are made by the dry or semi-dry process, and as small defects are not permissible, they are usually carefully dried before burning to prevent checking. They are usually muffled or boxed to prevent injury to the color by fire-flashing. They are very expensive, on account of the great care required in making and burning, and the limited demands for a given design. They are therefore sold by the piece and run from 5 to 60 cents each.

Enamel Brick are the glazed face brick that are beginning to meet with much favor in this country. They have been very largely used in England, especially for the interiors of buildings on account of the beautiful smooth surface and the great variety of color that is possible. The body consists of a hard burned red or fireclay brick that has been dipped in a glaze and which is subsequently fired in a special enamelling kiln, until the glaze fuses on tot he surface of the brick. The white enamel brick is especially desirable for hallways, bathrooms, and similar places, where a light-reflecting or an impervious sanitary article is desired. The great difficulty to overcome in manufacturing enamel brick is to prevent the crazing or fine cracking of the enamel, which is due to the difference in expansion between the dense glass surface and the soft, porous body of the brick. This has caused the failure of many firms which have attempted the difficult task of producing a salable enamelled brick, or one which will not craze. Only one company is making enamelled brick in Missouri at present. This is Hydraulic Press Brick Co., of St. Louis, and it has only succeeded after

ENAMELLING KILNS.

years of experimenting. The four enamelling kilns are shown in plate XXXVI. The body may be a red brick, but the results have been much more satisfactory with fireclay bricks. The size of enamel brick is usually the same as stock brick, or $8\frac{3}{8}$ by $4\frac{1}{4}$ by $2\frac{3}{8}$ inches. The excessive handling and great care required in the second or enamel burning, which is usually done in saggers, make these brick very expensive, so that the American-made ware cost from $60.00 to $80.00 a thousand, and the imported English brick which are slightly larger and have to pay a duty that at present amounts to 30 per cent ad valorem, cost $75.00 to $100.00 a thousand. The English are still ahead of us in this branch of brick-making, especially as they successfully burn and enamel the brick in one firing and without the use of saggers. But as this branch of brick-making is comparatively recent in this country, being yet in its infancy, better and cheaper goods are sure to be made in this very attractive line of ornamental brick.

PROCESSES OF BRICK MANUFACTURE.

DRY AND SEMI-DRY PRESS METHOD.

Storing. In manufacturing brick by the dry or semi-dry press processes the clay is gathered in a dry condition, at least as dry as soil usually exists (when it contains 3 to 6 per cent of moisture) and is stored in large sheds, where it is allowed to "mellow" for at least several weeks, the longer the period of storing the better. By thus storing the clay in large bodies, the moisture becomes uniformly distributed through the clay by capillary action, the lumps and clods soften, the organic matter, such as roots, grass and leaves, decay, and the clay gives a much more satisfactory product if sufficient time is allowed for this ripening, "sweating" or "mellowing" as it is termed.

The sheds are skeleton structures and consist of a high central ridge-pole with parallel side ribs, on which is nailed common boarding at a steep slope, with heavy lap joints to keep out the water. They are from 20 to 25 feet high at the center ridge-pole, and slope away on each side at an angle of about 30 degrees to within 4 to 5 feet of the ground. They are made from 40 to 80 feet wide, and from 100 to 400 feet in length. A typical clay shed on a sloping field is shown in plate XXXVII.

Gathering. The clay is gathered or harvested by first plowing it loose to a depth of two to six inches with light plows, gang plows, cultivaters or disc plows, after which it is usually allowed to dry out several hours in the sun and wind, if in the summer and for a day or two in the spring and fall. When sufficiently dry, it is usually scraped into winrows, and then shovelled into one-horse dump-carts by gangs

of hand-shovelers. Instead of hauling the clay into the sheds with carts, wheel scrapers are sometimes employed, especially if the haul is short, and recently a special automatic clay gatherer has been devised. This clay gatherer consists of a large central iron cylinder, with an open top, around which revolve, a series of scoops or buckets that can be thrown in or out of action by the driver in gathering the clay. The driver runs over the freshly plowed field or along the winrow of heaped-up clay, and by a clutch throws the revolving scoops into action which elevates the clay into the iron cylinder in a similar manner as a bucket elevator. When the cylinder is filled the buckets are thrown out of action, the load is hauled into the clay shed, where on unloosening a catch, the iron cylinder revolves 180 degrees, allowing the clay to fall out. It can be worked without stopping, by the driver, and the load is quickly gathered and quickly dumped, with no loss of time in hauling. The draught is very heavy on the team, in loading especially, as a guard rack has to be dropped in front of the buckets to enable them to pick up a full load. This machine was originally brought out to replace scrapers in ordinary earthwork but it proved a failure on account of its clogging and sticking up with clay in wet weather, but this objection does not hold in gathering dry clay. While the wagon and shoveling crew require a larger number of men, it is still a favorite method where the haul is long, as there is less clay left on the field, less clay lost in hauling, fewer teams employed and the work is much lighter on the horses.

Sufficient clay should be housed to run the plant at least two months to tide over wet weather and ensure an ample supply of dry clay, and the longer it can be stored the easier and better the clay works, but as the cost of gathering the clay ranges from 50 cents to $1.00 a thousand brick made, depending on the length of haul, method employed, character of clay and local wages, it locks up considerable capital if a large plant attempts to store a six to twelve months' supply. The clay sheds usually adjoin the brickyard, so that the clay can be wheeled in barrows, cars or carts, according to the length of the shed, direct to the pulverizer. At the yard of the National Brick and Quarry Co., of St. Louis, the clay sheds are on top of a hill above the brickyard, to which the clay is lowered by a gravity tramway.

On the exhaustion of the clay at two of the yards of the Hydraulic Press Brick Co., of St. Louis, the clay was harvested several miles away (at Ferguson and Selma), from whence it was shipped to the works in gondola or flat cars.

Pulverizing. For pulverizing the dry clay the "squirrel cage" or centrifugal disintegrator is usually employed, and a mill 40 inches in

A DRY-CLAY SHED.

diameter is able to pulverize, in ten hours, enough clay for 50,000 brick. Toothed rolls for coarse crushing are also employed in combination, but the latter has the objection of rolling the clays into sheets unless followed by a disintegrator. Dry-pans have not been used on this class of clays, as they do not need so heavy a machine. By jacketing the disintegrator with steam, the tendency of the clay when damp to adhere to the casing of the mills is almost entirely prevented.

Screening. The pulverized clay is elevated by a cup.elevator to a screen-tower, where it is usually screened in rotary screens or trommels. The screens range from 8- to 10-mesh for common brick and from 12- to 16-mesh for stock and ornamental brick. The screened clay is fed directly to the machine in the dry clay process, but is slightly moistened, either in a pug-mill or a revolving mixing mill or steamed in a conveying mill in the semi-dry process before going to the machine. If this water is added before pulverizing, or the very damp clay is used direct from the bank, it clogs the machinery by sticking. Hence the clay is dried out before gathering in either process to ensure regularity in running and freedom from choking. The press works more freely and with fewer interruptions if fed with dry clay, but it is more difficult to preserve the sharp edges and angles, for they readily rub off if the clay is not slightly damp. This objection is largely removed in the semi-dry process in the better bonding of the particles of clay, but more time is required to dry off this additional water in burning the brick.

Pressing. The clay is fed into the machine in a slightly damp pulverulent form that coheres slightly when pressed in the hand, and a large variety of machines for making brick are employed. They all depend on the same principle, or of filling a mould-box with the pulverized clay, and then subjecting it to pressure. The various mechanical devices that are used to secure a vertical pressure and extruding the pressed brick are the subjects of numerous patents. A number of these machines have been developed in St. Louis, as the Ross-Keller, Triumph, Lyons, Columbian, Progress or Kuloges and Fernholtz machines.

An important contribution to brick machines is in the development of the hydraulic press by Mr. M. N. Graves, superintendent of the Hydraulic Press Brick Co. This machine was originally brought out at Cleveland, Ohio, about the year 1856, by Ethan Rogers, the inventor, where it proved a failure. The patents were purchased by Messrs. E. C. Sterling and Graves. Under the latter's ingenuity it has been developed into a most efficient and satisfactory machine. The success of this machine has been so great that several attempts have been

made to at least take advantage of the hydraulic principle employed. In the hydraulic machine, as perfected, the pressure is produced by a pair of top and bottom hydraulic rams on which a light pressure of 240 pounds to the square inch is first applied followed by a high pressure of 3,700 pounds that completes the forming of the brick. This subjects each brick to an ultimate pressure of 40 tons. A view of the press is shown in plate XXXV, which shows the large low pressure cylinder immediately above the dies, with the small high pressure on top; on the left are the valves for controlling the admission and exhaust of the water.

The other machines for making dry-press brick are usually based on the principle of the toggle joint, or levers, or cams for obtaining the pressure on the brick.

A radically different type of machine from those already mentioned has been used to a limited extent in Missouri, which consists of a pair of trip hammers that beat the clay into the mould boxes. It is intended for semi-dry clay, and while the machine is simple, the brick are not uniform in thickness, and the machine has a very limited capacity.

The ever present trouble of expelling the air in moulding clay products is not avoided in the dry or semi-dry systems, as the die enters the mould-box so rapidly as to scarcely give an opportunity for the complete expulsion of the air. Small vent holes are left in the top and bottom dies for its escape, but at the high speed with which common brick are made they do not give sufficient time for its escape. When the movements of the top and bottom dies are equal, the air accumulates as a film or layer near the middle of the brick, and cause it to split open on the release of the pressure. This difficulty is overcome if the pressure is applied slowly, as is done with ornamental brick. The wear of the dies and mould boxes is severe, and several patented designs have been introduced to take up the wear and preserve the edges and angles. For if this is not done, the brick increase in size, from the wear of the boxes while the sharpness of the edges and angles is lost.

Setting. The brick are set in the kiln direct from the dry or semi-dry machine, being usually trucked on two-wheel buggies in which the body rests on carriage springs. It is necessary to set the brick in pairs face to face, in order to obtain one face of uniform color. The brick are usually set 38 to 42 high in up-draught kilns, and from 28 to 32 high in down-draught kilns. The usual settle in the St. Louis district with a silicious loess clay ranges between 9 and 10 inches for

UP-DRAUGHT KILNS.

medium burns, and 11 to 12 inches for hard burns, when set 40 courses high.

Burning. It is necessary to water-smoke the brick very slowly to prevent checking and cracking on account of the difficulty the moisture has in escaping from such a dense body, and from six to eight days are allowed for the drying and water-smoking. The subsequent firing and settling of the brick takes from four to six days longer, when the kiln is sealed and usually allowed a week to cool. Wood is used for the water-smoking stage and occasionally coke, but after the brick have become so hot that there is no further danger of choking the passages with soot, coal is usually employed to complete the burning. The coal should be as free from sulphur as possible, if stock or ornamental brick are to be burned, and the material should be boxed in or muffled to avoid fire-flashing.

Kilns. Up-draught kilns are almost always used to burn common building brick (plate XXXVIII), while down-draught kilns should be used for burning stock or ornamental brick; for the former type of kiln will produce 20 to 40 per cent of salmon, which in the latter can be reduced to 5 to 15 per cent. The brick that are exposed to the direct flames of the fire in up-draught kilns, known as "arch" or "eye" brick, are always more or less damaged by flashing and slagging from the adhering of ashes carried over by the draught. These arch brick are also warped or misshapen, if slightly overheated, from the heavy weight they have to carry, and they are usually only suitable for sewers, foundation and backing brick. The top course in a down-draught kiln is always fire-flashed and injured in color by the ashes that are carried over by the draught, but the brick are perfect in shape, and usually very hard, so that if not checked, they are very desirable for sidewalks, or sewers or foundations, and under the name of rough hard command a higher price than arch brick. The joint loss from the heavy percentage of salmon in the upper part of an up-draught kiln, and the damaged, misshapen and fire-flashed brick in the arches, necessitates the use of the down-draught kiln for burning such high-grade brick as stock, ornamental or enameled. The up-draught kiln costs from one-half to one-fourth as much of a down-draught kiln of equal capacity, and is much less expensive to keep in repair. The up-draught type of kiln is shown in plate XXXVIII, from the Hydraulic Press Brick yard No. 2, and the down-draught kiln in plate XXIX from the National Brick and Quarry Co.'s yard.

STIFF-MUD PROCESS.

Common brick are made by the stiff-mud process in the same manner as vitrified brick, as already described. As the clay is more readily crushed than the shale, centrifugal disintegrators or rolls are generally used for first grinding the clay, instead of dry-pans, as in the latter case. The ground clay is tempered with water to a stiff mud in the pug-mill, is then fed to a machine, which is worked by either a continuous revolving augur or reciprocating, intermittent plunger. It is forced through either a broad die that makes an end-cut brick, the former being the more popular method, especially if the bricks are afterwards repressed. If the clay is stiff enough the brick are taken from the cutting table of the machine, are placed on pallets, racks, or cars, and dried either in open sheds or tunnel dryers. If stock or ornamental face brick are desired, the brick are repressed on coming from the mud machine, while they are still in a plastic condition, and are handled and dried with more care. When dried they are set in the kiln in the usual manner, but they can be burned more rapidly than press-brick, as the water has less difficulty in escaping, there is less moisture to expel, and the kiln does not have to run as a dryer for two or three days before it is safe to raise the heat. The details of the manufacture of building brick are essentially similar to those of vitrified brick.

SOFT-MUD PROCESS.

In the soft-mud process, the clay is not ground or pulverized, but is softened and tempered direct from the bank, either in soak-pits or ring-pits. In the cruder form of soak-pits employed at small hand yards the clay is thrown down from the banks into piles two to four feet in depth, and then thoroughly drenched with water and allowed to soak 24 to 48 hours, with a moderate amount of working over by shovelling. In larger yards, the clay is wheeled from the bank into long rectangular pits that are three feet deep with the bottom and sides lined with boards and is wetted down in layers. After soaking for about 24 hours, to permit the uniform permeation of the mass by the water, the clay is shovelled out and fed to the brick machine.

In the ring-pit system of working a circular pit of 20 to 30 feet in diameter and 2 to 3 feet deep, is similarly filled with clay direct from the bank, and after being well wetted with water is allowed to soak for 10 to 20 hours. It is then tempered or pugged by running through the clay a large narrow wheel that hangs from a cross-beam, the latter is footed into a central post and is dragged around the pit by horses, and occasionally by steam power. The ring-pit system of tempering gives an excellent, uniform paste if sufficiently worked and is the best method

of tempering soft mud. It is the standard method employed in the East, especially in the famous Philadelphia district, but as yet has not been adopted to any great extent in Missouri.

The soft mud is moulded into brick either by hand or machines, the former being employed in smaller or temporary yards, and the latter where the demand is large or permanent. In the hand system of moulding, the brickmaker is provided with a table to which the soft mud is wheeled in barrows from the temporary pit. The moulder tears off sufficient clay from the pile to more than make a brick which he rapidly forms into a rough ball or "waulk" using sand very freely to prevent its adhering to his hands or the table and then with a peculiar knack throws it into a wooden mould. The clay is so soft that it fills out the mould completely, leaving a slight surplus on top, which is cut off with a wire. A slight draft is given to the mould-box to enable the brick to drop out when reversed, and it is carried off in a pallet by boys, called off-bearers, and set on a carefully levelled yard to dry in the open air. The mould-boxes are made to contain one to six bricks and are made of wood. They need frequent renewal as the sand wears them rather rapidly and the brick tend to become larger and larger the longer they are employed. A brickmaker, with one man wheeling mud to him, and two boys taking away the brick, usually makes 3,000 brick in a day, though sometimes 5,000 are made, and instances are known in competitions, of a moulder making as many as 10,000 brick a day. The usual "stint" of 3,000 is generally moulded in 7 to 8 hours, after which the brick are turned or edged to prevent warping or cracking by unequal drying, and those of the previous days' work, if dry, are hacked or piled up under cover, to protect them from storms. In the hot weather, the moulder often begins as early as four o'clock in the morning and usually completes his work by noon, thus avoiding the excessive heat. The moulding of brick seems a simple matter, yet it calls for an amount of skill, endurance and strength that takes considerable time to acquire, especially if such hard work as 5,000 brick a day are required.

If stock or face brick are desired, the bricks are allowed to dry out to a firm stiff body that will bear handling without marking and are repressed in a hand-press. The brick require frequent turning in drying, especially if exposed to the sun, and many clays are so strong as to crack badly unless slowly dried under cover in racks or sheds where they can be protected from both sun and wind.

While hand-made brick are quite light and porous, from the slight pressure given on throwing the clay into the mould-box, they possess

considerable strength and are usually able to successfully resist frost, even when not perfectly burned.

In machine moulding, the soft mud or tempered clay is fed into a vertical pug-mill, which is provided with revolving blades that force the clay into mould-boxes which are regularly fed, and withdrawn from the machine as fast as filled. The mould-boxes are dipped into sand before they are fed to the machine to prevent the adhesion of the clay to the sides of the mould. Such a soft-mud machine has a capacity of 15,000 to 20,000 brick a day, and is usually run by one man who withdraws and trims the mould-boxes, a second man who feeds the clay, and a third man who sands and feeds the mould-boxes, while from two to four off-bearers, according to the length of run, take away the brick to the yard for drying. If the moulds are doused in water, which also prevents the clay from sticking if liberally used, the brick made are known as "slap" brick, as they come out of the moulds in such a soft condition as to require great care in handling to prevent deforming and marking. Soft-mud brick, whether made by hand or machine, unless repressed, are apt to be irregular in size, and imperfect in shape, as the clay is usually tempered so soft that the brick are liable to be injured in handling. If the brick, while drying on the yard, are exposed to a rainstorm, though an effort is usually made to hack them under cover when a storm is seen approaching, the corners, angles, and edges are more or less washed off, and the surface is spotted with the impression of rain drops, and they are given the name of "washed brick" by the trade and were formerly regarded as an almost total loss. But if they are only slightly spotted (whether natural or artificial) they have recently become quite popular, and are known as rain-marked brick. Soft-mud brick are often burned in case or temporary kilns, the walls of which are built of fresh brick that is very liberally daubed with mud on the outside. They are often burned with wood, especially in small country yards, which prevent a good color from being obtained from the joint action of insufficient heat, the whitening effect of wood ashes carried up by the draft and the excess of sand that is used in moulding.

Adobe brick are soft mud blocks that have only been dried, not burned. They are used very largely throughout Utah and Nevada, where the rainfall is so slight that they are fairly durable, especially if veneered with stucco. They make a very cool brick, however, as the walls are made very thick, but they are liable to "wilt" or soften under a prolonged, heavy rain.

Statistics of the Brickyards of Missouri.

ADAIR COUNTY.

5 yards, 5 kilns; produced in 1891, 2,100,000 brick, valued at $13,200.

Name.	Location.	Kind of yard.	Process.	Machine. Kind.	Machine. Capacity.	H. P. engine.	Boilers.	Kilns. Number.	Kilns. Kind.	Kilns. Capacity.	Mode of drying.	Product.	Output in 1890.	Output in 1891.	Value of product in 1891.
Barnard, John	Kirksville	Hand.	Wet					1			Air	Common		500,000	$3,000
Black & Son	"	"	"					1			"	"		500,000	3,000
Ivie, J. M. (old yard)	"	Mach.	Dry	Eureka	20,000			1	Case	120,000	"	"	120,000	600,000	4,200
Ivie, J. M. (new yd.)	"	"	Stiff-mud	Centennial	20,000	40	1	1	"	120,000	"	"			
Parcells, E. W	"	Hand.	Wet					1			"	"		500,000	3,000

ANDREW COUNTY.

1 yard, 1 kiln; produced in 1891, 300,000 brick, valued at $2,100.

Name.	Location.	Kind of yard.	Process.	Machine. Kind.	Machine. Capacity.	H. P. engine.	Boilers.	Kilns. Number.	Kilns. Kind.	Kilns. Capacity.	Mode of drying.	Product.	Output in 1890.	Output in 1891.	Value of product in 1891.
Clark, Geo.	Savannah							1				Common		300,000	$2,100

ATCHISON COUNTY.

6 yards, 7 kilns; produced in 1891, 1,550,000 brick, valued at $10,100.

Name.	Location.	Kind of yard.	Process.	Machine. Kind.	Machine. Capacity.	H. P. engine.	Boilers.	Kilns. Number.	Kilns. Kind.	Kilns. Capacity.	Mode of drying.	Product.	Output in 1890.	Output in 1891.	Value of product in 1891.
West & Weaver	Fairfax							1						100,000	$700
	Langdon							1						100,000	700
Chastain & Son	Magnet	Hand.						2	Case	100,000	Air	Common	160,000	750,000	4,500
West Bros	Rockport							1						200,000	1,400
Harrison	Tarkio	Hand.	Wet					1	Case		Air	Common		200,000	1,400
Hudson, Wilson	Watson							1						200,000	1,400

STATISTICS OF BRICKYARDS—Continued.

AUDRAIN COUNTY.

3 yards, 4 kilns; produced in 1891, 2,100,000, valued at $14,700.

Name.	Location.	Kind of yard.	Process.	Machine. Kind	Machine. Capacity.	H. P. engine.	Boilers.	Kilns. Number	Kilns. Kind	Kilns. Capacity.	Mode of drying	Product.	Output in 1890.	Output in 1891.	Value of product in 1891.
Beeby, E., & Son	Laddonia	Hand.	Wet					1	Case	100,000	Air	Common	400,000	400,000	$2,800
Harrison & Ketter	Mexico	"	"					2	Clamp		"	"		1,500,000	10,500
Johnson, R. H.	Vandalia							1						200,000	1,400

BARRY COUNTY.

2 yards, 4 kilns; produced in 1891, 375,000, valued at $2,625.

Name.	Location.	Kind of yard.	Process.	Machine. Kind	Machine. Capacity.	H. P. engine.	Boilers.	Kilns. Number	Kilns. Kind	Kilns. Capacity.	Mode of drying	Product.	Output in 1890.	Output in 1891.	Value of product in 1891.
Cook, Ed.	Monett	Hand.	Wet					2	Case	120,000	Air	Common			
Drake, J. B., & Son.	"	H & M	"	Old Reliable	10,000			2	Clamp	125,000	"	"	150,000	375,000	$2,625

BARTON COUNTY.

1 yard, one kiln.

Name.	Location.	Kind of yard.	Process.	Machine. Kind	Machine. Capacity.	H. P. engine.	Boilers.	Kilns. Number	Kilns. Kind	Kilns. Capacity.	Mode of drying	Product.	Output in 1890.	Output in 1891.	Value of product in 1891.
Gill & Aldrich	Golden City	Mach.	Semi-dry	Mascott Auger	12,000	10		1	Up-draft	20,000	Air	Com., tile.			

BATES COUNTY.

2 yards, 7 kilns; produced in 1891, 1,950,000 brick, valued at $13,650.

Name.	Location.	Kind of yard.	Process.	Machine. Kind	Machine. Capacity.	H. P. engine.	Boilers.	Kilns. Number	Kilns. Kind	Kilns. Capacity.	Mode of drying	Product.	Output in 1890.	Output in 1891.	Value of product in 1891.
Power & Bro.	Butler							2	Clamp					650,000	$4,550
Anderson, J. D	Rich Hill	Mach.	Wet	Hand repress.	5,000			5	"	300,000		Common	1,200,000	1,300,000	9 100

BOONE COUNTY.

3 yards, 5 kilns; produced in 1891, 1,700,000, valued at $10,700.

Eaton, Geo. T	Centralia	Mach.	Wet	Quaker	10,000			1	Updraft	140,000	Steam	Common.	500,000	500,000	$3,500
Kenton, Pickett	"	Hand.	"					1	Case	100,000	Air	"			
Fay, J. D	Columbia	Mach.	Dry	Challenge	20,000	30	1	3	Clamp	415,000		"	1,200,000	1,200,000	7,200

BUCHANAN COUNTY.

15 yards, 48 kilns; produced in 1891, 21,100,000, valued at $131,575.

Beemer, Theo	E. Atchison							2						500,000	$3,500
Blass, Henry	"							2						500,000	3,500
Beumeler, John	St. Joseph	Hand						2	Clamp	250,000	Air	Common	10,000	500,000	3,000
Davis Brick Co	"	"	Wet					3	"	340,000	"	"	1,700,000	1,700,000	8,925
Duffy, D. H	"	"	"					3	"	400,000	"	"	2,500,000	2,500,000	13,750
Erb Bros	"	"	"					2	"	250,000	"	"	650,000	500,000	2,500
Felling Hagedorn Co	"	Mach.	Dry-press	Triumph	30,000	30	1	4	"	360,000	"				
Fredrick, Chas. D	"	Hand	Wet					3	"	300,000	"	Common	1,500,000	1,600,000	9,200
Friede Bros. & Bode	"	"	"					3	"	320,000	"	"	2,400,000	1,600,000	8,800
Hermann, Jos. & Co	E. St. Joseph	"	"					2	"					600,000	4,200
Herman & Horn	St. Joseph	"	"					3	"	450,000	Air	Common		2,000,000	12,000
St. Joseph Pr. B. Co	"	Mach.	Wet and dry	Eureka	20,000	50	1	11	"&D.D	475,000		Com. stock	7,000,000	7,000,000	49,000
Strop	"	Hand.	"					3	"		Air	Common		750,000	4,500
Valentine, Wm	"	"	"					3	"	250,000	"	"	750,000	750,000	4,500
Whittington, J. J	"							2						600,000	4,200

STATISTICS OF BRICKYARDS—Continued.

BOLLINGER COUNTY.

1 yard, 1 kiln; produced in 1891, 100,000 brick, valued at $700.

Name.	Location.	Kind of yard..	Process.	Machine. Kind	Machine. Capacity.	H. P. engine..	Boilers...	Kilns. Number.	Kilns. Kind	Kilns. Capacity.	Mode of drying	Product.	Output in 1890	Output in 1891.	Value of product in 1891..
Newell, Terrel	Marble Hill........	....	....	....	.....	....	..	1	....	....	....	....	....	100,000	$700

BUTLER COUNTY.

1 yard, 2 kilns; produced in 1891, 450,000 brick, valued at $3,150.

Walker, L. B. & Co	Poplar Bluff......	Hand	Wet..... ..	Repress.......	2,000	..		2	....	....	Air...	Com., stock	450,000	450,000	$3,150

CALDWELL COUNTY.

3 yards, 3 kilns; produced in 1891, 480,000 brick, valued at $3,210.

McCubbin, Wm M...	Braymer..........	Hand	Wet.........	....	.....	...	..	1	Case.....	....	Air...	Common. ..	250,000	300,000	$1,950
Snyder, Geo. W.....	Hamilton........	"	"	....	.....	...	..	1	....	....	"	" ..	80,000	80,000	560
Browning, W. D....	Polo.	"	"	....	.....	...	..	1	Case....	....	" ..	" ..	....	100,000	700

CASS COUNTY.

3 yards, 8 kilns; produced in 1891, 1,825,000 brick, valued at $11,825.

Dixon, E. H.........	Creighton.	Hand.	Wet.........	....	.....	...	..	2	Clamp...	....	Air...	Common ..	325,000	325,000	$1,625
Sair, E.........	Harrisonville.....	" ..	"	....	.....	...	..	2	" ...	150,000	" ..	" ..	....	300,000	1,800
Pleasant Hill B. Co.	Pleasant Hill......	Mach	"	Quaker.........	35,000	....	1	4	" ...	....	" ..	" ..	1,700,000	1,200,000	8,400

CALLAWAY COUNTY.

5 yards, 13 kilns; produced in 1891, 3,500,000 brick, valued at $21,100.

Harrison, J. A.	Auxvasse	Hand	Wet					1				Common		200,000	$1,300
Cumberland, J. K.	Fulton	Mach	"	Eagle; Martin	20,000			6	Case		Air	"	3,000,000	3,000,000	18,000
Fetter, Joe	"	Hand	"					2	"		"	"			
Harris, John	"	"	"					1	"	100,000	"	"	100,000		
Ismay, A.	"	"	"					3	"		"	"	300,000	300,000	1,800

CAPE GIRARDEAU COUNTY.

4 yards, 8 kilns; produced in 1891, 2,250,000 brick, valued at $11,500.

Bode & Klagus	Cape Girardeau	Hand	Wet					2	Clamp	150,000	Air	Common	600,000	600,000	$2,850
Daues & Schroder	"	"	"					2	"	265,000	"	"		750,000	3,700
Schlueter, Julius	"	"	"					2	"	310,000	"	"		600,000	3,000
Oldenhoener, Wm.	Jackson	Mach	"	Grand Aut'mat	8,000			2	"	125,000	"	"	300,000	300,000	1,050

CARROLL COUNTY.

8 yards, 12 kilns; produced in 1891, 2,750,000 brick, valued at $17,050.

Zerr, L.	Bosworth							1						100,000	$700
Crouch & Harding	Carrollton	Mach.	Stiff-mud	Centennial	30,000	25	1	2	D.D.Cla'p	200,000	Air	Common		200,000	1,200
Parker Bros	"	Hand.	Wet					2	Clamp					1,000,000	5,000
Woodson	"	"	"					2	"	150,000	Air	Common		500,000	3,500
Ballard, Chas. W.	DeWitt	"	"					1	"	110,000	"	"	250,000	250,000	1,750
Lionberry, B.	Hale	"	"					1				"		100,000	700
Scranton, A. H.	"	"	"					1				"		100,000	700
	Norborne	" ?						2	Clamp			"		500,000	3,500

STATISTICS OF BRICKYARDS—Continued.

CEDAR COUNTY.

1 yard, 1 kiln; produced in 1891, 100,000 brick, valued at $700.

Name.	Location.	Kind of yard..	Process.	Machine. Kind . .	Machine. Capacity.	H. P. engine..	Boilers.........	Kilns. Number .	Kilns. Kind.	Kilns. Capacity.	Mode of drying	Product.	Output in 1890.	Output in 1891.	Value of product in 1891..
Grubb, R. M........	Jerico.......	....	....	....	......	...	..	1	....	....	....	....	....	100,000	$700

CHARITON COUNTY.

8 yards, 9 kilns; produced in 1891, 1,900,000 brick, valued at $12,900.

Beazley, T. J. & Son	Brunswick	Mach.	Wet	....	20,000	25	1	2	Clamp ...	175,000	Air ...	Common ..	....	500,000	$3,500
Brunswick B & T.Co	"	" ..	Dry.....	Boyd..........	20,000	30	1	5	D.D Cla'p	250,000	" ..	" ..	1,200,000	1,200,000	8,400
Synn, A. J	"	Hand.	Wet	....	.. ..	....	..	2	Case......	100,000	" ..	" ..	200,000	200,000	1,000

CHRISTIAN COUNTY.

1 yard, 8 kilns.

Umborfs	Billings...........	Hand.	....	....	.....	.. .	..	2	Case......	100,000	Air ...	Common ..	....	....	....

CLAY COUNTY.

2 yards, 7 kilns; produced in 1891, 3,000,000 brick, valued at $19,000.

Jackson & Hardwick	Birmingham	Mach.	Semi-dry	Kells	25,000	25	1	3	Clamp ...	300,000	......	Common ..	2,000,000	2,000,000	$12,000
....	Minaville.........	......	....	....	......	...	..	4	" ..	... .	......	" ..	....	1,000,000	7,000

CLARK COUNTY.

4 yards, 8 kilns; produced in 1891, 1,650,000 brick, valued at $9,550.

DeBord, J. P.	Kahoka	Mach.	Wet	Dry press	25,000	....	..	2	Clamp	200,000	Air	Common	250,000	250,000	$1,750
Eaton & Son	"	Hand.	"	....	.....	....	..	2	Cl. & Ca.	540,000	....	"	1,000,000	1,000,000	5,000
Mosely & Taylor	"	....	....	....	.....	....	..	2	....	....	....	....	....	200,000	1,400
Webster, Thos. W.	"	....	....	....	.....	....	..	2	....	....	....	....	....	200,000	1,400

CLINTON COUNTY.

2 yards, 2 kilns; produced in 1891, 300,000 brick, valued at $2,100.

....	Cameron	....	....	....	.....	....	..	1	....	....	....	....	....	200,000	$1,400
Casey, C. E. & J. D.	Gower	....	....	....	.....	....	..	1	....	....	....	....	....	100,000	700

COLE COUNTY.

2 yards, 5 kilns; produced in 1891, 1,800,000 brick, valued at $11,600.

Jefferson City B. Co	Jefferson City	Mach.	Wet	Grand aut.	20,000	22	1	3	Case	280,000	Air	Common	1,000,000	1,000,000	$6,000
Pohl, B H.	"	"	"	Tiffany	25,000	...	1	2	Clamp	180,000	"	"	800,000	800,000	5,600

COOPER COUNTY.

2 yards, 4 kilns; produced in 1891, 800,000 brick, valued at $4,800.

Reform School	Boonville	Mach.	Soft mud	Quaker	40,000	....	..	2	Clamp	170,000	Air	Common	800,000	800,000	$4,800
Stammerjohn, Claus	"	Hand.	....	....	.....	....	..	2	"	140,000	....	....	....	....	....

STATISTICS OF BRICKYARDS—Continued.

DAVIESS COUNTY.

4 yards, 7 kilns; produced in 1894, 900,000 brick, valued at $5,500.

Name.	Location.	Kind of yard	Process.	Machine. Kind	Machine. Capacity.	H. P. engine	Boilers	Kilns. Number	Kilns. Kind	Kilns. Capacity.	Mode of drying	Product.	Output in 1890.	Output in 1891.	Value of product in 1891
Griffiths, F.	Gallatin	Mach.	Wet	Quaker				2	Clamp		Air	Common			
Tomlinson, J.	"	Hand.	"					2	Case		"	"	300,000	300,000	$1,800
Tomlinson, J. L.	"	"	"					2	Clamp		"	"		500,000	3,000
Griffith, Francis	Jamesport							1				"		100,000	700

DALLAS COUNTY.

1 yard, 1 kiln; produced in 1891, 340,000 brick, valued at $1,700.

Name.	Location.	Kind of yard	Process.	Machine. Kind	Machine. Capacity.	H. P. engine	Boilers	Kilns. Number	Kilns. Kind	Kilns. Capacity.	Mode of drying	Product.	Output in 1890.	Output in 1891.	Value of product in 1891
Johnson, C. F	Buffalo	Hand.	Wet					1	Case	300,000	Air	Common		340,000	$1,700

DENT COUNTY.

Name.	Location.	Kind of yard	Process.	Machine. Kind	Machine. Capacity.	H. P. engine	Boilers	Kilns. Number	Kilns. Kind	Kilns. Capacity.	Mode of drying	Product.	Output in 1890.	Output in 1891.	Value of product in 1891
Dyes, E. L	Salem	Hand.	Wet					2	Case	200,000	Air	Common			
Organ, J. E	"	Mach.	Soft mud	Tiffany	10,000			1							

DUNKLIN COUNTY.

1 yard, 1 kiln; produced in 1891, 250,000 brick, valued at $2,250.

Name.	Location.	Kind of yard	Process.	Machine. Kind	Machine. Capacity.	H. P. engine	Boilers	Kilns. Number	Kilns. Kind	Kilns. Capacity.	Mode of drying	Product.	Output in 1890.	Output in 1891.	Value of product in 1891
Whitney, C. M	Kennett	Hand.	Wet					1	Case	200,000	Air	Common		250,090	$2,250

FRANKLIN COUNTY.

5 yards, 9 kilns; produced in 1891, 1,405,000 brick, valued at $8,530.

Angerer, Fred.	St. Clair	Hand.	Wet					1		105,000	Air	Common		100,000	$700
Barwe & Foerster	Washington	"	"					2	Clamp	140,000	"	"	250,000	280,000	1,680
Brocker, John	"	"	"					2			"	"		300,000	1,800
Hollmann, Henry C.	"	"	"					2	Case	170,000	"	"	340,000	425,000	2,550
Stumpe, Frank	"	"	"					2		150,000	"	"	300,000	300,000	1,800

GASCONADE COUNTY.

2 yards, 4 kilns; produced in 1891, 1,000,000 brick, valued at $7,000.

Hansen, Chas	Hermann							2						500,000	$3,500
Valet, F	"							2						500,000	3,500

GENTRY COUNTY.

5 yards, 11 kilns; produced in 1891, 1,706,000 brick, valued at $12,292.

Barkley Brick Co.	Albany	Hand.	Wet					2				Common		500,000	$3,500
Cross, S. B. & Son	"	"	"					3	Case	200,000	Air	"			
Darlington, T. & B.W	Darlington	Mach.	Semi-dry	Adrian	15,000	20	1	1	Cir. D. D.	30,000	"	"		500,000	3,500
Hipp, F. G.	"	"	Stiff mud	McKinsey	20,000	25	1	2	Case&cir.	237,000	"	"	6,000	6,000	42
Valin & Mulholland	Stanberry	"	"	Penfield	40,000	105	2	3	Clamp	300,000	"	"	800,000	700,000	5,250

STATISTICS OF BRICKYARDS—Continued.

GREENE COUNTY.

7 yards, 14 kilns; produced in 1891, 3,700,000 brick, valued at $22,325.

Name.	Location.	Kind of yard.	Process.	Machine. Kind.	Machine. Capacity.	H. P. engine.	Boilers.	Kilns. Number.	Kilns. Kind.	Kilns. Capacity.	Mode of drying.	Product.	Output in 1890.	Output in 1891.	Value of product in 1891.
....	Ash Grove	Hand.						1	Clamp	240,000		Common		300,000	$2,100
Boll, Jacob	Springfield	Mach	Stiff mud	Little Wonder.	25,000	50	1	2	Case	90,000	Air	"		700,000	4,025
Gear, Lloyd & Co	"	Hand.	Wet					3	Clamp	300,000	"	"		1,200,000	7,200
McCain	"	"	"					2			"				
Quick, John	"							2						500,000	3,000
Rands, T. J	"							2						500,000	3,000
Reynolds	"							2						500,000	3,000

GRUNDY COUNTY.

6 yards, 7 kilns; produced in 1891, 2,600,000 brick, valued at $18,200.

Name.	Location.	Kind of yard.	Process.	Machine. Kind.	Machine. Capacity.	H. P. engine.	Boilers.	Kilns. Number.	Kilns. Kind.	Kilns. Capacity.	Mode of drying.	Product.	Output in 1890.	Output in 1891.	Value of product in 1891.
Grear & Sons	Gault	Mach.	Stiff mud	DecaturLea'r	20,000			1	Case	160,000	Air &S	Common			
Griffith, Francis	"							1				"		200,000	$1,400
Rugniers, Fred	"	Hand.	Wet					1	Case	250,000	Air	"		500,000	3,500
....	Speckards							1	"			"		200,000	1,400
Griffith, Francis	Trenton	Mach.	Wet	Quaker				2	Clamp	200,000	Air	"	800,000	1,500,000	10,500
Hall, S	"							1						200,000	1,400

HARRISON COUNTY.

1 yard, 1 kiln; produced in 1891, 200,000 brick, valued at $1,400.

Noll, Jacob	Bethany							1						200,000	$1,400

HENRY COUNTY.

7 yards, 16 kilns; produced in 1891, 2,100,000 brick, valued at $14,550

Yorks, J. M	Brownington	Hand.	Wet					1			Air	Common	200,000		
Hendrix, R. W	Calhoun	"	"					2	1 cir.,1 sq.	28,000	"	"	250,000	250,000	$1,750
Foote, E. L	Clinton	Mach.	Semi-dry	New Ohio	30,000	40	2	3	Clamp	150,000	"	"	500,000	1,000,000	7,000
Moorehead, H. D	"	Hand.	Wet					3	"	175,000		"	700,000	700,000	4,200
Valle & Dehardt	"	"	"					2	"	150,000	Air	"		150,000	900
Keith & Perry	Deepwater	Mach.	Stiff mud	Kells	30,000	35		4	"		Kiln	Com., pav.			
Smith, W. H	Windsor							1						100,000	700

HOWARD COUNTY.

4 yards, 6 kilns; produced in 1891, 1,200,000, brick valued at $8,400.

Heffmaus	Armstrong	Hand.	Wet					1	Clamp	100,000	Air	Common		200,000	$1,400
Washburn, B. W	Fayette.							2						500,000	3,500
Burdle Bros	Glasgow							2	Case					500,000	3,500
McClintock	"	Hand	Semi-dry					1	"		Air	Common			

HOWELL COUNTY.

1 yard, 2 kilns; produced in 1891, 300,000 brick, valued at $1,750.

Powers, Wm	Willow Springs	Hand.	Wet					2	Champ	250,000	Air	Common	300,000	300,000	$1,750

STATISTICS OF BRICKYARDS—Continued.

HOLT COUNTY.

5 yards, 6 kilns; produced in 1891, 1,680,000 brick, valued at $13,800.

Name.	Location.	Kind of yard..	Process.	Machine. Kind. ...	Machine. Capacity	H. P. engine..	Boilers........	Kilns. Number..	Kilns. Kind	Kilns. Capacity	Mode of drying	Product.	Output in 1890.	Output in 1891	Value of product in 1891..
King, J. T..	Corning	Hand.	Wet					2	Clamp...	150,000	Air...	Common...		$380,000	$3,040
McMunn & Quick	Forest City	"	"					1	Case	130,000	"	"			
Wood, C. J.	"	"	"					1			"	"	200,000	200,000	1,300
	Maitland							1						200,000	1,400
Whobrey, J. B. & Son	Mound City	Mach.	Dry	Andrus	10,000			1	Case	200,000	Air...	Common...	900,000	900,000	8,100

HICKORY COUNTY.

Name.	Location.	Kind of yard..	Process.	Machine. Kind. ...	Machine. Capacity	H. P. engine..	Boilers........	Kilns. Number..	Kilns. Kind	Kilns. Capacity	Mode of drying	Product.	Output in 1890.	Output in 1891	Value of product in 1891..
Moore	Wheatland	Hand.	Wet					2	Case	100,000	Air...	Common			

JASPER COUNTY.

5 yards, 11 kilns; produced in 1891, 5,100,000 brick, valued at $32,900.

Name.	Location.	Kind of yard..	Process.	Machine. Kind. ...	Machine. Capacity	H. P. engine..	Boilers........	Kilns. Number..	Kilns. Kind	Kilns. Capacity	Mode of drying	Product.	Output in 1890.	Output in 1891	Value of product in 1891..
Queen City Brick Co.	Carthage	Mach.	Wet	New Quaker..	30,000	50	1	3	Updraft..	740,000	Air...	Common...	2,800,000	2,800,000	$16,800
Merrell & Andrews..	Joplin	Hand.	"					2		200,000	"	"		800,000	5,600
Sargeant, J. B. & Son	"							1						200,000	1,400
	Oronogo	Mach.			10,000			3	Clamp...			"		500,000	3,500
Merrell & Andrews..	Webb City	Hand.	Wet					2	"	200,000	Air...	"		800,000	5,600

JACKSON COUNTY.

23 yards, 86 kilns; produced in 1891, 54,980,000 brick, valued at $444,180.

Porter, John	Centropolis							2						1,000,000	$7,000
Howell, G. W.	Dodson							1						100,000	700
Randall, Wm. L.	Independence	Mach.	Mud	Quaker	15,000			2	Clamp.	250,000	Air	Common		460,000	2,880
Sly, Fred	"							2						1,000,000	7,000
Strust, W.	"	Hand.	Wet					2	Clamp	200,000	Air	Common		600,000	3,600
Adams, J. O. & Sons	Kansas City	Mach.	Semi-dry	Adrian	30,000	40	1	2	"	250,000	Steam	"	1,800,000	1,500,000	9,000
Behney, M. B.	"							2						500,000	3,000
Gates & Brooks	"	Mach.	Wet	Quaker	40,000	40	1	4	Clamp	260,000	Air	Common			
Harris Bros. Br. Co.	"							3	Case					3,000,000	18,000
Hoezel Bros.	"							2						500,000	8,000
House, G. W.	"	Hand.	Wet					2	Clamp	225,000	Air	Common	1,000,000	1,200,000	6,000
K. C. Hy. P. B. Co.	"	Mach	Dry	Hydr'lic press.	70,000	125	5	20	U. & D. D	800,000	Steam	Stk & orna.	16,660,582	17,000,000	204,000
Terra Cotta L. Co.	"	"	Stiff mud	Clark.	33,000	125	3	9	D. D. cl.	290,000	"	Com. & f. p.			
Mense, Mathias S.	"	Hand	Wet					3	Clamp		Air			3,000,000	18,000
Murdock, Rob't	"	"	"					4	"			Com. & stk.		3,500,000	21,000
Norcross Bros.	"	Mach.	"	Potts	40,000	35	1		"	300,000	Air	Common		3,000,000	18,000
O. K. Tryshammer	"	"	Dry	Tryshammer	40,000			4	"			"		3,000,000	18,000
Schrage, H.	"	"	Wet	Chief	10,000			2	"	240,000	Air	"			
Schrecks, Henry	"	Hand.	"					2	"	200,000	"	"	600,000	600,000	3,000
Seddon & Edwards	"	Mach.	Stiff mud	Adrian	30,000	100	3	5	"	260,000	A. & S	"		4,000,000	24,000
Standard Brick Co.	"	"		Wallace				2	"	150,000				2,000,000	12,000
Stuckenberg, H. C.	"	"	Stiff mud	Little Wonder	25,000	40	2	4	Updraft	230,000	Steam	Common	1,000,000	1,000,000	6,000
Underwood Br. Co.	"	"	Dry	Martin	80,000	80	1	7	Clamp	300,000	Air	Press & C.	7,500,000	8,000,000	60,000

STATISTICS OF BRICKYARDS—Continued.

JEFFERSON COUNTY.

3 yards, 5 kilns; produced in 1891, 720,000 brick, valued at $5,040.

Name.	Location.	Kind of yard..	Process.	Machine. Kind	Machine. Capacity	H. P. engine..	Boilers........	Kilns. Number..	Kilns. Kind.....	Kilns. Capacity	Mode of drying	Product.	Output in 1890.	Output in 1891.	Value of product in 1891..
Hermann, Otto......	DeSoto............	Mach.	Wet	Martin	14,000	10	1	2	D-drght .	180,000	Air ...	Common...	720,000	720,000	$5,040
Martin, James.......	Hillsboro	Hand.	"	....	.....	....	..	1	Case.....	160,000	" ..	" ...	....	....	....
Miller, Louis & Sons.	Festus	Mach.	Soft mud	Martin	17,000	....	..	2	Clamp ...	150,000	Shed .	" ...	....	....	....

JOHNSON COUNTY.

1 yard, 2 kilns; produced in 1891, 500,000 brick, valued at $3,500.

Wade, Jos	Warrensburg	....	....	....	.....	....	..	2	....	....	....	....	....	500,000	$3,500

KNOX COUNTY.

1 yard, 2 kilns; produced in 1891, 500,000 brick, valued at $3,000.

Parker, P. W........	Edina	Hand.	Wet	....	......	....	..	2	Clamp ...	240,000	....	Common...	400,000	500,000	$3,000

LACLEDE COUNTY.

1 yard, 2 kilns; produced in 1891, 740,000 brick, valued at $5,000.

Lingweiler, J. G....	Lebanon..........	Hand.	Wet	....	.....	....	..	1	Clamp ...	785,000	Air ...	Common...	740,000	740,000	$5,000

LAFAYETTE COUNTY.

10 yards, 19 kilns; produced in 1891, 9,720,000 brick, valued at $29,680.

Berrie, H. B.	Lexington	Mach.	Dry	Lyon	20,000	25	1	2	Clamp	250,000	Air	Common	1,500,000	1,500,000	$9,000
Bird & Co.	Higginsville	Hand.	Wet					2	Case	120,000		"		500,000	3,000
Bosselmann, H.	Concordia	Mach.		Hoosier plungr	11,500			1	Clamp	65,000	Air	"		300,000	2,400
Campbell & Ligon	Higginsville.	"	Semi-dry	Nolan	20,000	12	2	1	"	175,000	Steam	"		200,000	2,400
Farrar, Geo.	Lexington	"	Dry	Boyd	18,000	25	1	2	"	200,000	Air	"	6,000,000	6,000,000	48,000
Kneedler & Breisf'd	Higginsville	"	Wet	Craiger	25,000			2				"		500,000	3,000
Krumsick, H	Corder	"		Phœnix				2	U. D. cir.			"		500,000	3,500
Triumph Fr. B. Co.	Lexington.	"		Triumph	30,000	40	1	4	Clamp	300,000		St'k & Com.			
Niemann,, Gottlieb.	Alma.	"	Wet	Penfield	6,000			1	Case	100,000	Air	Common	100,000	100,000	800
Shaefernolte, Fr.	Higginsville	"	Stiff-mud	Penfield	6,000			2	Rct. & Cir	100,000	"	Common	100,000	120,000	780

LAWRENCE COUNTY.

6 yards, 10 kilns; produced in 1891, 2,777,000 brick, valued at $16,287.

Bradley	Aurora	Mach.	Stiff-mud	Brewer	30,000	24		2	Clamp	145,000	Air	Common		150,000	$750
Brewster & Co	"	Hand.	Wet					2			"	"		602,000	3,612
Houck, Ed	"	"	"					2	Case	200,000	"	"	1,218,000	1,025,000	5,125
Cochran, H. C.	Mt Vernon	"	"					1						200,000	1,200
Smith & Rouk	"							1						200,000	1,400
Greer Bros.	Pierce City	Hand.	Wet					2	Case	180,000	Air	Common		600,000	4,200

LEWIS COUNTY.

1 yard, 1 kiln; produced in 1891, 200,000 brick, valued at $1,200.

Ewald, Sam'l	LaBelle	Hand.	Wet					1	Case	120,000	Air.	Common	200,000	200,000	$1,200

STATISTICS OF BRICKYARDS—Continued.

LINCOLN COUNTY.

3 yards, 3 kilns; produced in 1891, 560,000 brick, valued at $3,920.

Name.	Location.	Kind of yard.	Process.	Machine. Kind	Machine. Capacity.	H. P. engine.	Boilers.	Kilns. Number	Kilns. Kind	Kilns. Capacity.	Mode of drying	Product.	Output in 1890.	Output in 1891.	Value of product in 1891.
Morris, W. H	Elsberry	Hand.	Wet					1	Case		Air	Common		300,000	$2,100
Krebs, Sam	Troy							1						200,000	1,400
Winfield Tile Works.	Winfield	Mach.	Wet	Brewster		20	1	1	D. D		Air	Com., tile		60,000	420

LINN COUNTY.

9 yards, 15 kilns; produced in 1891, 3,100,000 brick, valued at $20,100.

Name.	Location.	Kind of yard.	Process.	Machine. Kind	Machine. Capacity.	H. P. engine.	Boilers.	Kilns. Number	Kilns. Kind	Kilns. Capacity.	Mode of drying	Product.	Output in 1890.	Output in 1891.	Value of product in 1891.
Heppel, John	Brookfield							2						500,000	$3,500
Hiland, Wm	"	Hand.	Wet					2	Case	100,000	Air	Common	500,000	500,000	3,000
King T. & B. Wks	"	Mach.	Stiff mud	Centennial	10,000	25	1	1	"		"	"			
Vanhouten, S	"	Hand.	Wet					2	Clamp		"	"		500,000	3,000
Peters & Bro	Browning	" ?						2				"		300,000	2,100
Cummings, C. G	Linneus	" ?						2	Case			"		500,000	3,500
	Marcelline							1						100,000	700
	Meadville	Hand?						1	Case			Common		100,000	700
Johnson, Henry	Purdin	"	Wet					2	"		Air	"	600,000	600,000	3,600

LIVINGSTON COUNTY.

3 yards, 4 kilns; produced in 1891, 2,000,000 brick, valued at $13,500.

Curran, L.	Chillicothe	Hand.	Wet					1	Clamp		Air	Common		500,000	$8,000
Nesbit, Wm	"							2						500,000	8,500
Seiser Bros.	"	Hand.	Wet					1	Clamp	200,000	Air	Common	1,100,000	1,000,000	7,000
MACON COUNTY.															
6 yards, 8 kilns; produced in 1891, 1,960,000 brick valued at $12,400.															
Hamilton, A. H.	Economy	Hand.	Wet					1				Common		200,000	$1,400
Moore, Steven	"	"	"					1				"		200,000	1,400
Little, W. S.	La Plata	"	"					1	Case	150,000	Air	"		400,000	2,400
Brown, J C.	Macon	"	"					2	Clamp	120,000	"	"	360,000	460,000	2,300
Faucher, B	"	"	"					2	Case	100,000	"	"	500,000	500,000	3,500
White	"	"	"					1	"	100,000	"	"	200,000	200,000	1,400
MADISON COUNTY.															
1 yard, 1 kiln; produced in 1891, 200,000 brick, valued at $1,600.															
Beard, Rufus	Fredericktown	Hand.	Wet					1	Case	100,000	Air	Common		200,000	$1,600
MARION COUNTY.															
3 yards, 6 kilns; produced in 1891, 1,675,000 brick, valued at $11,000.															
Bulkley, A. W	Hannibal	Hand.	Wet					1	Case	175,000	Air	Common	175,000	175,000	$1,000
Ford, John	"	Mach.	Soft mud	Anderson	20,000			3	Clamp	900,000	"	"	1,000,000	1,000,000	6,500
Shepherd & Smoot	Palmyra							2						500,000	3,500

STATISTICS OF BRICKYARDS—Continued.

MERCER COUNTY.

6 yards, 9 kilns; produced in 1891, 1,100,000 brick, valued at $7,500.

Name.	Location.	Kind of yard..	Process.	Machine. Kind . ..	Machine. Capacity.	H. P. engine..	Boilers........	Kilns. Number.	Kilns. Kind.	Kilns. Capacity.	Mode of drying	Product.	Output in 1890.	Output in 1891.	Value of product in 1891..
Grubb, R. M.	Jerico							1						100,000	$700
Griffith, J. S.	Lineville	Hand.	Wet					1	Case		Air.	Common.			
Wickline & Forsythe	"	"	"					1	"	100,000	"	"	100,000	100,000	$700
Griffith, F.	Mercer	"	"					2	Case, cl'p	300,000	"	"		300,000	2,100
Whitlines, Lon	"	"	"					1	Case		"	"		200,000	1,200
Bolster, C	Princeton	"	"					2				"		500,000	3,500
Meek & Biggers	"							2							

MISSISSIPPI COUNTY.

1 yard, 2 kilns; produced in 1891, 400,000 brick, valued at $2,800.

Name.	Location.	Kind of yard..	Process.	Machine. Kind . ..	Machine. Capacity.	H. P. engine..	Boilers........	Kilns. Number.	Kilns. Kind.	Kilns. Capacity.	Mode of drying	Product.	Output in 1890.	Output in 1891.	Value of product in 1891..
Pratt, W. D.	Charleston	Mach.	Wet	Old Reliable	12,000			2	Clamp	150,000		Common.	400,000	400,000	$2,800

MONITEAU COUNTY.

2 yards, 2 kilns; produced in 1891, 300,000 brick, valued at $2,100

Name.	Location.	Kind of yard..	Process.	Machine. Kind . ..	Machine. Capacity.	H. P. engine..	Boilers........	Kilns. Number.	Kilns. Kind.	Kilns. Capacity.	Mode of drying	Product.	Output in 1890.	Output in 1891.	Value of product in 1891..
Mueller, Chas. H.	California							1						100,000	$700
Clark, Tyne	Tipton	Hand.	Wet					1	Clamp	180,000	Air	Common.		200,000	1,400

MONROE COUNTY.

3 yards, 3 kilns; produced in 1891, 450,000 brick, valued at $3,300.

Johnson, J. W	Madison	Hand						1				Common		100,000	$700
Johnston, Eyra	Monroe City	"	Wet					1	Clamp	200,000	Air	"	150,000	200,000	1,400
Seibert, G. W	Paris	"	"					1	Case		"	"	150,000	150,000	1,200

MORGAN COUNTY.

2 yards, 2 kilns; produced in 1891, 120,000 brick, valued at $800.

Hummel, John M	Florence	Mach.	Wet	Gentler	3000			1	D. D.	10,000	Steam	Common	10,000	20,000	$100
Rankin, J. H	Versailles							1						100,000	700

MONTGOMERY COUNTY.

2 yards, 2 kilns; produced in 1891, 400,000 brick, valued at $2,800.

Milam, J. W	Montgomery City							1						200,000	$1,400
Weise, Geo.	"							1						200,000	1,400
	Wellsville	Hand	Wet					1	Case	120,000					

NEWTON COUNTY.

2 yards, 2 kilns; produced in 1891, 400,000 brick, valued at $2,800.

	Neosho							1	Clamp			Common		200,000	$1,400
	"							1	"			"		200,000	1,400

STATISTICS OF BRICKYARDS—Continued.

NODAWAY COUNTY.

10 yards, 20 kilns; producedin 1891 3,100,000 brick, valued at $21,700.

Name.	Location.	Kind of yard.	Process.	Machine. Kind	Machine. Capacity.	H. P. engine.	Boilers.	Kilns. Number.	Kilns. Kind	Kilns. Capacity.	Mode of drying.	Product.	Output in 1890.	Output in 1891.	Value of product in 1891.
Brinkman, Henry	Barnard	Hand	Wet					2	Case			Common		100,000	$700
Bollinger & Sayer	Burlington Jc	Mach.	Stiff mud	Penfield	10,000			3	"	147,000	Air	"	400,000	300,000	2,100
Wallace Bros	Clearmont	Hand.	Wet					1			"	"			
Baker, Jos	Guilford	"	"					1	Case	100,000	"	"			
Gladman, M. H	Hopkins	"	"					2	Clamp	250,000	"	"	500,000	500,000	3,500
Ashford, F. L	Maryville							3	Case			"	1,000,000	1,000,000	7,000
Shecks, F. L	"	Hand	Wet					3	"			"		1,000,000	7,000
Kinney, J. A	Pickering							2	D. D. & C			"		200,000	1,400
Grimes, Stephen	Quitman	Hand.	Wet					2	Case	100,000	Air	"			
Roberts, Norton	"	"	"					1	"	50,000	"	"			

OREGON COUNTY.

1 yard, 1 kiln; produced in 1891, 200,000 brick, valued at $1,000.

Name.	Location.	Kind of yard.	Process.	Machine. Kind	Machine. Capacity.	H. P. engine.	Boilers.	Kilns. Number.	Kilns. Kind	Kilns. Capacity.	Mode of drying.	Product.	Output in 1890.	Output in 1891.	Value of product in 1891.
Shaw, W. J	Thayer	Hand.	Wet					1	Clamp	80,000	Air	Common		200,000	$1,000

OSAGE COUNTY.

Name.	Location.	Kind of yard.	Process.	Machine. Kind	Machine. Capacity.	H. P. engine.	Boilers.	Kilns. Number.	Kilns. Kind	Kilns. Capacity.	Mode of drying.	Product.	Output in 1890.	Output in 1891.	Value of product in 1891.
Pahl, Jos.	Linn	Hand.	Wet					1	Case	600,000		Common.			

PERRY COUNTY.

8 yards, 9 kilns; produced in 1891, 1,010,000 brick, valued at $6,260.

Undriners, Jos	Uniontown	Hand.	Wet					1	Clamp	160,000	Air	Common		160,000	$960
Boehme & Jacobs	Altenburgh	"	"					1	Case	150,000	"	"	600,000	150,000	900
Goehl, G	"							1						100,000	700
Fenwick, J. Z	Brewer							1						100,000	700
Popp, John	Perryville	Hand.	Wet					2	Clamp	125,000	Air	Common	300,000	300,000	1,800
Grimmaw, Jas	Crosstown	"	"					1	Case	100,000	"	"		100,000	600
Ossiers	Perryville	"	"					1	"	100,000	"	"		100,000	600
Ganahl	"	"	"					1	"	100,000	"	"	100,000		

PETTIS COUNTY.

1 yard, 2 kilns; produced in 1891, 500,000 brick valued at $3,500.

	Sedalia	Hand.	Wet					2	Clamp			Common		500,000	$3,500

PIKE COUNTY.

6 yards, 11 kilns; produced in 1891, 2,280,000 brick, valued at $14,600.

Beebe, E., Son & Co	Bowling Green	Hand.	Wet					2	Clamp			Common	350,000	350,000	$2,100
McElroy, J. P	"							2						500,000	3,500
Blain, Jas	Clarksville	Hand.	Wet					1			Air	Common		230,000	1,600
Mefford & Jackson	Frankford	"	"					1			"	"		200,000	1,400
Grady Bros	Louisiana	"	"					1	Clamp	150,000	"	"			
Schurfeld, P	"	H & M.	"	Old Reliable	6,000			4	Updraft	380,000	"	"	1,900,000	1,000,000	6,000

STATISTICS OF BRICKYARDS—Continued.

PHELPS COUNTY.

1 yard, 1 kiln; produced in 1891 200,000 brick, valued at $1,400.

Name.	Location.	Kind of yard..	Process.	Machine. Kind	Machine. Capacity.	H. P. engine..	Boilers....	Kilns. Number.	Kilns. Kind	Kilns. Capacity.	Mode of drying	Product.	Output in 1890	Output in 1891.	Value of product in 1891..
Hamburg, John. ...	Rolla.	Hand.	Wet..........	....	.....	...	..	1	Case......	100,000	Air...	Common...	....	200,000	$1,400

POLK COUNTY.

2 yards, 5 kilns; produced in 1891, 450,000 brick, valued at $2,250.

Name.	Location.	Kind of yard..	Process.	Machine. Kind	Machine. Capacity.	H. P. engine..	Boilers....	Kilns. Number.	Kilns. Kind	Kilns. Capacity.	Mode of drying	Product.	Output in 1890	Output in 1891.	Value of product in 1891..
Moore	Bolivar	Hand.	Wet	....	.....	....	..	3	Case......	320,000	Air...	Common...	....	450,000	$2,250
Gill, Robt	Humansville....	"	"	....	.....	....	..	2	....	....	....	" ...	....	....	....

PUTNAM COUNTY.

2 yards, 4 kilns; produced in 1891, 1,000,000 brick, valued at $7,000.

Name.	Location.	Kind of yard..	Process.	Machine. Kind	Machine. Capacity.	H. P. engine..	Boilers....	Kilns. Number.	Kilns. Kind	Kilns. Capacity.	Mode of drying	Product.	Output in 1890	Output in 1891.	Value of product in 1891..
Townes, M. S.... ...	Unionville.........	Hand.	Wet	....	.....	....	..	2	....	....	....	Common...	....	500,000	$3,500
Washburn, H. A	"	"	"	....	.....	....	..	2	....	....	....	" ...	....	500,000	3,500

RALLS COUNTY.

2 yards, 3 kilns; produced in 1891, 300,000 brick, valued at $2,100.

Name.	Location.	Kind of yard..	Process.	Machine. Kind	Machine. Capacity.	H. P. engine..	Boilers....	Kilns. Number.	Kilns. Kind	Kilns. Capacity.	Mode of drying	Product.	Output in 1890	Output in 1891.	Value of product in 1891..
Simon, H. C....	New London	Hand	Wet	....	.....	....	..	2	Case.....	....	Air ...	Common...	....	300,000	$2,100
Winfree, R. W.......	Perry	"	"	....	.....	....	..	1	Updraft..	15,000	" ...	" ...	....	....	....

RANDOLPH COUNTY.

2 yards, 2 kilns; produced in 1891, 800,000 brick, valued at $5,600.

Hudson	Higbee	Hand.	Wet					1			Air	Common		200,000	$1,400
Heflin, W. J	Huntsville	"	"					1	Clamp	150,000	"	"	600,000	600,000	4,200

RAY COUNTY.

1 yard, 2 kilns; produced in 1891, 500,000 brick, valued at $3,500.

Parr, W. B	Richmond							2						500,000	$3,500

SALINE COUNTY.

7 yards, 12 kilns; produced in 1891, 1,525,000 brick, valued at $10,325.

Crouch, H	Arrow Rock							1						100,000	$700
Gilmore	Marshall							2						500,000	3,500
Rose Bros. & Mirkins	"	Mach.	Wet	Quaker	3,000	15	1	3	Clamp	250,000	Air	Common	150,000	150,000	1,050
Strop, George	"	Hand.	"					2	"	220,000	"	"	350,000	350,000	2,100
Edmonds, A. R	Miami							1						100,000	700
Corv, A. B	Mt. Leonard	Mach.	Wet	Frey Sheckler.	8,000	20	1	1	Clr. D. D.	9,000	Air	Common		5,000	35
Brookman & Heller.	Slater	"		Quaker	10,000			2	Case	175,000	"	"		320,000	2,240

SCOTT COUNTY.

1 yard, 1 kiln; produced in 1891, 100,000 brick, valued at $700.

Henson, Nacey	Sikeston							1						100,000	$700

STATISTICS OF BRICKYARDS—Continued.

SCOTLAND COUNTY.

5 yards, 6 kilns; produced in 1891, 800,000, brick, valued at $5,500.

Name.	Location.	Kind of yard.	Process.	Machine. Kind	Machine. Capacity	H. P. engine	Boilers	Kilns. Number	Kilns. Kind	Kilns. Capacity	Mode of drying	Product.	Output in 1890	Output in 1891	Value of product in 1891
Campbell	Arbela	Hand.	Wet					1	Case	100,000	Air	Common		200,000	$1,400
Mudd, G. W	Downing	"						1		100,000	"	"		100,000	700
Williamson & Co	Hazelville	"	Wet					2	Case		"			100,000	600
Kirkpatrick, M	Memphis	"						1				Common		200,000	1,400
Munroe, Geo	"	"						1				"		200,000	1,400

SCHUYLER COUNTY.

5 yards, 6 kilns; produced in 1891, 1,550,000 brick, valued at $10,625.

Name.	Location.	Kind of yard.	Process.	Machine. Kind	Machine. Capacity	H. P. engine	Boilers	Kilns. Number	Kilns. Kind	Kilns. Capacity	Mode of drying	Product.	Output in 1890	Output in 1891	Value of product in 1891
Crim & Noe	Lancaster							1						200,000	$1,400
Meals, C. W	Queen City							1						200,000	1,400
Ryan, J. H	"	Hand.	Wet					1	Clamp	200,000	Air	Common		600,000	4,200
Towles & Wilson	"							1						100,000	700
Wallace, W. Q	"	Hand.	Wet					2	Case		Air	Common	300,000	450,000	2,925

SHELBY COUNTY.

2 yards, 2 kilns; produced in 1891, 500,000 brick, valued at $3,400.

Name.	Location.	Kind of yard.	Process.	Machine. Kind	Machine. Capacity	H. P. engine	Boilers	Kilns. Number	Kilns. Kind	Kilns. Capacity	Mode of drying	Product.	Output in 1890	Output in 1891	Value of product in 1891
Betz, Chas	Clarence	Hand	Wet					1	Case	50,000				100,000	$600
Miles, W. T	Shelbina	Mach.	"	Quaker	15,000			1	"	160,000	Air	Common	400,000	400,000	2,800

STODDARD COUNTY.

1 yard, 1 kiln; produced in 1891, 400,000 brick, valued at $2,800.

Fuller & Grant	Dexter	Mach	Wet	Quaker				1	Clamp	200,000	Air	Common		400,000	$2,800

ST. CHARLES COUNTY.

6 yards, 12 kilns; produced in 1891, 5,340,000 brick, valued at $36,090.

Hammer, Geo	O'Fallon	Hand	Wet					1	Cl., D. D.	80,000	Air	Common	50,000	90,000	$540
I. X. L. P. B. Co	St. Charles	Mach.	Dry	Andrus	20,000		1	3	Updraft	200,000	"	"	1,000,000	1,280,000	7,200
Platter, Jos	"													500,000	3,500
St. Charles P. B. Co.	"	Mach.	Dry	Andrus, Boyd.	35,000	40	1	4	Cl., Eud.	315,000	Air	C., S. & P.	1,500,000	3,000,000	21,000
Tiemann, Fred	"	Hand	Wet					2	Case	210,000		Common	500,000	400,000	2,805
Sanders, Arnold	St. Peter.	"	"					1	Clamp	150,000	Air	Com., stock	150,000	150,000	1,050

ST. FRANCOIS COUNTY.

3 yards, 3 kilns; produced in 1891, 150,000 brick, valued at $5,250.

Sleeth, H	DeLassus	Hand.	Wet					1			Air	Common	250,000	250,000	$1,750
White Bros	"							1						200,000	1,400
Pratt, J. R	Farmington	Hand.	Wet					1	Clamp	140,000	Air	Common		300,000	2,100

STE. GENEVIEVE COUNTY.

2 yards, 3 kilns; produced in 1891, 200,000 brick, valued at $1,200.

Rehm, Chas	Ste. Genevieve	Hand.	Wet					2	Case, Cl.	200,000		Common	200,000	200,000	$1,200
Heibel, Peter	Weingarten	"	"					1	Case	100,000		"			

STATISTICS OF BRICKYARDS—Continued.

ST. LOUIS CITY.

39 yards, 195 kilns; produced in 1891, 244,745,000 brick, valued at $2,227,647.

Name.	Location.	Kind of yard..	Process.	Machine. Kind	Machine. Capacity.	H. P. engine..	Boilers.........	Kilns. Number	Kilns. Kind	Kilns. Capacity.	Mode of drying	Product.	Output in 1890.	Output in 1891.	Value of product in 1891..
American Press B Co	20th & Prairie.....	Mach.	Dry-press ...	Lyon.	30,000	40	1	4	Clamp . .	250,000	Air ...	Common ..	8,000,000	8,000,000	$50,000
Barnett Brick Wks .	Newstead ave . .	" ..	Dry	Kennedy	20,000	40	1	4	" ..	285,000	" ...	" ..	4,000,000	4,500,000	31,500
Bergsieker & Bros ..	Glasgow ave	Hand	Wet	....	.....	...	..	2	" ..	150,000	" ...	" ..	900,000	1,050,000	6,300
Blow Brick Co.......	514 Kansas str.....	Mach.	Dry	Boyd	......	..	..	3	" ..	....	....	Com., stock	....	2,000,000	11,000
Bollman, Aug	18th, Cass, O'Fal'n	Hand	Wet	....	......	.....	..	1	" ..	....	Air ...	Common ..	1,000,000	....	... .
Broadway Brick W.	813 E Grand	Mach.	Dry, semi dr.	1 Simpson . 1 Chisholen 2 Andrus...	65,000	40	1	4	3 Repell, 1 Com'n.	995,000	" ...	Stock, com.	6,300,000	6,300,000	44,100
Brockschmidt, H. ..	Manchester road	" ..	Wet	Quaker	.....	.....	..	3	Clamp. ..	....	" ...	Common ..	....	3,000,000	21,000
Central Brick Wks..	Clayton road.....	Hand	"	....	....	..	..	7	" ..	170,000	" ...	" ..	600,000	1,000,000	5,000
College Hill Pr.B.Co	College & Linton..	Mach.	Dry	3 Triumph.. 1 Challenge	125000	60	1	6	" ..	300,000	....	Com., stock	10,000,000	18,000,000	116,000
Compton Ave. B.W.	Atlantic & Compt.	" ..	Semi-dry	....	... .	.....	..	4	" ..	....	....	Com.,stk.,O	8,000,000	....	....
Cote Brilliant P.B.Co	5216 St. Louis ave	" ..	Dry	Simpson	60,000	60	1	6	" ..	720,000	....	"	....	1,000,000	6,000
Eureka Pr. Brick Co.	4251 N. 11th str....	" ..	"	Dry-press	.....	.....	1	2	" ..	280,000	....	Com., stock	3,000,000	500,000	3,000
Grote & Hilkerban'r	4314 N. 20th str....	Hand	Wet	....	....	.....	..	2	" ..	....	Air ..	Common ..	800,000	2,000,000	12,000
Heidebur, Bernard.	VonPhul & College	"	"	....	...	.....	..	1	" ..	180,000	" ...	" .	500,000	500,000	2,500
Humann, F., & Co..	2301 Union ave ...	Mach.	Soft mud	Grand Autom.	17,000	15	1	2	" ..	225,000	" ...	" ..	1,350,000	2,700,000	12,525
Hydraulic Pr. Br.Co	Six yards in St. L.	" ..	Dry	Royer hydraul	45,000	....	..	32 27	" Patent ...	365,000	" ...	Stk.,or.com	90,000,000	90,000,000	1,000,000
Illinois Sup.& Con.Co	....	" ..	"	Simpson,Boyd, Andrus,Beater	65,000	40	2	5	" ...	240,000	....	Com., stock	....	7,000,000	57,000
Ither, A....	Sidney & Californ.	" ..	"	Andrus	90,000	125	2	5	Clamp ...	300,000	....	Com.,stk O.	....	15,000,000	121,250
Koenig, H. C	Osage & Marine .	" ..	Soft mud, dry	Martin, Grand auto., Eureka	76,000	45	1	5	2 " ... 3 Patent .	500,000	....	"	3,500,000	3,500,000	20,125

Kunst, F....	Nebraska & Utah.	Hand	Wet	....	......	......		2	Clamp ...	175,000	Air ...	Common ..	875,000	875,000	4,594
Lion Press Brick Co.	Barrack & Patom.	Mach.	Dry..........	Lyon	20,000	20	20	4	" ..	150,000	....	" ..	... .	1,800,000	9,000
Menke, Adam	1425 College	Hand	Wet	....	......	......	..	2	" ..	410,000	Air ...	" ..	1,200,000	1,200,000	7,200
Missouri Pr. B. Co ..	Osage & Marine...	Mach	Wet and dry	Martin, Eureka Little Giant..	56,000	....	1	2 2	Patent... Clamp...	235,000	" ...	Stk., or.com	6,000,000	6,000,000	36,000
Niemann, A. H......	Jefferson & Utah .	" ..	Soft mud	Grand autom.	17,000	12	1	3	Rappel...	170,000	" ...	Common ..	2,890,000	2,890,000	15,172
Oehler, Otto.........	President & Cleon	Hand	Wet	.. ..	. ..	....	..	3	Clamp ...	560,000	" ...	Com.,stock	1,260,000	1,260,000	6,930
Ranahl, C. B	S. St. Louis ave...	"	"	....	......	. ..	..	2	" ..	220,000	" ...	Common ..	250,000	....	....
Repking, J. H.......	Nebraska & Wyo.	Mach.	Soft mud ...	Grand autom.	18,000	12	1	3	" ..	165,000	" ...	" ..	2,475,000	2,475,000	13,612
Schlingmann, Henry	19th and Penrose.	Hand	Wet	....	....	..	..	2	" ..	170,000	" ...	" ..	765,000	765,000	3,442
Schlingmann, Wm..	14th and Penrose.	Mach.	Mud	Grand autom.	17,000	10	1	3	" ..	170,000	" ...	" ..	1,300,000	1,530,000	8,797
Schweer Brick Co...	Broadway & Osce.	" ..	Dry..........	Lyon	25,000	30	1	4	" ..	300,000	" ...	" ..	... .	....	....
Spengemann, C.	Michigan av.	Hand	Wet	....	....			2	" ..	....	" ...	" ..	1,200,000	1,200,000	6,000
Steinkamper, F. ...	Ashland & Euclid.	"	"	....	.. .	..	..	1	" ..	165,000	" ...	" ..	....	500,000	2,750
Steinkamper, F.....	Ashland, King's H	Mach.	Soft mud	Grand autom	17,000	25	1	3	" ..	225,000	" ...	" ..	1,500,000	2,500,000	13,750
Stocke & Beckmann	....	" ..	Dry..........	Lyon, Eureka Simpson.....	70,000	...	1	5	" ..	300,000	....	Com.,stock	4,000,000	4,000,000	28,000
Stuckenberg, John..	Jefferson & Utah.	" ..	Soft mud	Grand autom.	17,000	10	1	3	Rappel .	160,000	Air ...	"	3,200,000	3,200,000	16,800
Superior Pr. Br. Co.	3190 S. King's H...	" ..	Dry.	Lyon	34,000	40	1	6	Clamp ..	280,000	" ...	"	....	5,000,000	35,000
Tower Grove B. W..	3255 S. King's H...	" ..	"	Eureka, Lyon.	47,000	85	1	5	" ..	300,000	" ...	"	500,000	3,500,000	21,000
Union Press Br. Co..	Natural bridge R.	" ..	Wet and dry	2 Swords, 1 Hyd	96,000	....	3	18	" ..	300,000	" ...	"	40,000,000	40,000,000	480,000
Gratiot Brick Co	Gratiot station ...	" ..	Dry..... . ..	....	......	....	..	1	" ..	.. ...	....	... ...	....	....	....

STATISTICS OF BRICKYARDS—Continued.

ST. LOUIS COUNTY.

11 yards, 18 kilns; produced in 1891, 5,275,000, valued at $35,300.

Name.	Location.	Kind of yard.	Process.	Machine. Kind	Machine. Capacity.	H. P. engine.	Boilers.	Kilns. Number	Kilns. Kind.	Kilns. Capacity.	Mode of drying.	Product.	Output in 1890.	Output in 1891.	Value of product in 1891.
Hoch, Henry	Bellfountaine							1						100,000	$700
Sconhorst, John	"							1						100,000	700
Sedivee, Mich	Fenton							1						100,000	700
Richter, Anton	Florissant	Hand	Wet					1	Clamp		Air	Common		500,000	2,750
Glick Bros	Luxemburg	Mach.	Dry	Simpson	20,000			3	"	200,000		"		1,500,000	10,500
Blow Brick Co.	"	"	"	Boyd	20,000			4	"	420,000		"		2,000,000	14,000
Shores	Mehlville							1						100,000	700
National Brick Co.	"	Mach.	Dry.	Triumph	30,000	60	1	7	End. D. D	240,000		Stock & com			
Lamb	Wellston	"	Soft mud	Grand aut	17,000			2	Windg'n.	185,000	Air	Common			
Ritterbush, F. W.	"	Hand	Wet					2	Clamp	175,000	"	"	875,000	875,000	5,250
McGregory	Rose Hill	Mach.	Dry.	McGregory	40,000				"	175,000					

STONE COUNTY.

Name.	Location.	Kind of yard.	Process.	Machine. Kind	Machine. Capacity.	H. P. engine.	Boilers.	Kilns. Number	Kilns. Kind.	Kilns. Capacity.	Mode of drying.	Product.	Output in 1890.	Output in 1891.	Value of product in 1891.
Seaman, F	Galena	Hand	Wet					1	Case	100,000		Common	100,000		

SULLIVAN COUNTY.

6 yards, 6 kilns; produced in 1891, 800,000 brick, valued at $5,600.

Erskine	Castle							1				Common		100,000	$700
Neal, Clem	"							1	Case		Air	"		100,000	700
Griffith, Francis	Harris							1				"		100,000	700
Greer, Hiram	Milan	Hand.	Wet					1	Case	100,000	Air	"		500,000	3,500
Hoffman & May	"	Mach.	Semi-dry	Andrus	20,000			1	"	170,000	"	"			
Hudnall, J.	"	Hand.	Wet					1	"	150,000	"	"			

TEXAS COUNTY.

2 yard, 2 kilns; produced in 1891, 200,000 brick, valued at $1,400.

	Mountain Grove	Hand.	Wet					1	Case	150,000		Common		200,000	$1,400
Fredericks, A.	Houston	"	"					1	"	80,000		"			

VERNON COUNTY.

2 yards, 5 kilns; produced in 1891, 2,600,000 brick, valued at $17,600.

Daly, J. E.	Nevada	Mach.	Wet	Chief			1	3	Clamp	750,000	Air	Common		2,000,000	$14,000
Mims, John & Co.	"	"	"	Quaker	25,000			2	"	250,000	"	"		600,000	3,600

WARREN COUNTY.

2 yards, 3 kilns; produced in 1891, 340,000 brick, valued at $2,040.

Siehermann, Henry	Truesdale	Hand.	Wet					1	Clamp	70,000	Air	Common	140,000	140,000	$840
Day, J. G.	Warrenton	"	"					2	"	100,000	"	"	200,000	200,000	1,200

STATISTICS OF BRICKYARDS—Continued.

WORTH COUNTY.

2 yards, 2 kilns; produced in 1891, 200,000 brick, valued at $1,400.

Name.	Location.	Kind of yard.	Process.	Machine.		H. P. engine.	Boilers.	Kilns.			Mode of drying.	Product.	Output in 1890.	Output in 1891.	Value of product in 1891.
				Kind.	Capacity.			Number.	Kind.	Capacity.					
Lamb, Frémont	Denver	Hand.	Wet					1	Case	100,000	Air	Common	100,000	100,000	$700
Abbott & Duke	Sheriden							1						100,000	700

CHAPTER XVI.

RAILROAD BALLAST CLAYS AND INDUSTRY.

In the comparatively new industry of burning gumbo for railroad ballast Missouri is conspicuously in the lead, in the magnitude of the industry, and in being the scene of the great improvements that have taken place in carrying it on by machinery. The value of the annual output is about $1,000,000, on a capital investment of about $500,000, and about 1,000,000 tons of clay are required each year. The successful displacement of hand-burning by several efficient machines took place in this state. The northern portion of Missouri is especially favorable for its development in having an abundance of clays that are suitable for this purpose, and in being very poor in natural rock ballast. The southern part of the state, on the contrary, is very rich in excellent rock ballast, and poor in suitable ballast clays, and as yet no ballast has been burnt south of the Missouri river.

Burnt gumbo or clay ballast is a red, gravel-like material that varies from pea to nut in size, is very irregular and angular in shape, decidedly porous, hard, and resembles hard-burned broken brick. It is made from very strong, impure clays that possess the property of decrepitation or falling into fragments on drying and burning, in consequence of their great strength and shrinkage, while they are so impure as to easily burn hard at a low temperature, or a red heat.

USES OF BURNT GUMBO.

Burnt gumbo has been mainly used for railroad ballast, for which it is admirably adapted. It is also used for road metal or macadam, for walks (in place of gravel) and as a deadener for floors.

Railroad Ballast. Buring clay for railroad ballast has been practiced for a long time abroad, but was only introduced into this country so recently as 1884, when a patent was taken out by Wm. Davy, an Englishman, for this purpose. It is primarily intended for those places in which natural rock ballast is unattainable, but the improvements that have been made in preparing it, and its advantages over stone, have enabled it to successfully compete with the latter in the districts that are in the heart of a limestone bluff country. It has been in use

as long as twelve years on the Chicago, Burlington and Quincy railroad, and is now very largely used on the Missouri roads of this extensive system. It is also used by the Wabash, the Atchison, Topeka and Santa Fe, the Chicago, Rock Island and Pacific, and Missouri, Kansas and Texas railroad systems, in the northern half of the state, and its use has rapidly grown within the past five years. Its manufacture is carried on by two companies that make a specialty of supplying railroads, and are known as the Davy Clay Ballast Co., of Kenosha, Wisconsin, and the Western Burnt Clay Ballast and Paving Brick Co., of Cameron, Missouri, of which the Chicago Burnt Clay Ballast Co. is a recent off-shoot.

The advantages of burnt gumbo for railroad ballast are:

(1) Low first cost.

(2) Ease and economy in handling.

(3) Elasticity of the roadbed.

(4) Freedom from vegetation, and

(5) Lack of trouble from snow and ice.

The low first cost arises from the cheapness with which the clay can be dug and burned, as slack is used for fuel. The clays most suitable are the heavy, cold, sour, black soils that are termed "gumbo" soils by the farmer, and which are usually of no value except for pasture, as it does not usually pay to till them. They are, therefore, the cheapest kind of land, and the farmers sometimes give the material away in order to obtain the pond that results from the excavation. The plant can be located along the track, thus saving the expense of transportation and trackage that is usually necessary when quarrying rock ballast. With the recent improvements in machinery for digging and spreading the clay, slacking the pits, and loading the burnt gumbo with steam shovels, the cost of the burnt clay delivered on the cars has been brought down from 65 to 35 cents a cubic yard, whereas broken stone ranges from 50 to 90 cents. The small size and lightness of the burnt clay make it very easy material to handle with a shovel or, to tramp with a tie, or to move off of flat cars with a snow plough. It can be handled and worked as readily and freely as gravel, and at a considerable saving in time and expense over broken stone in being handled from the pit to the roadbed. It makes a very elastic, smooth, easy riding roadbed, if used freely. Usually from 12 to 18 inches are employed which make a very elastic foundation that is easier on the rolling stock, in being free from the shock and deadness of broken stone. As the humus and other vegetable matter is thoroughly burnt out of it, no weeds can grow on it, until it has lain long enough to ac-

cumulate sufficient dust, so that it is freer from vegetation than broken stone. On account of its warm red color, and peculiar texture, it absorbs the heat of the sun more rapidly in winter than broken stone and the snow and ice, therefore, melt from it more rapidly.

Thus far the manufacturers have especially avoided vitrifying the clay in order to retain its lightness and porosity, but if it be vitrified, by using more fuel, in order to increase the strength and hardness, it it would be rendered more durable by making it less sensitive to frost. As now made the weight ranges from 1,300 to 1,600 pounds to the cubic yard, according to the clay employed and thoroughness of the burning, which is 25 to 50 per cent less than broken stone. It is capable of absorbing 20 to 30 gallons of water for each cubic yard, which is about equivalent to a heavy rainstorm.

Macadam. For macadamizing purposes it is not as durable as a good tough rock, as it crushes and wears too rapidly if the traffic is heavy, but for county roads where the teams are few and the loads moderate, it would prove quite desirable. It should be used on the very numerous county roads in the northern part of the state that become almost impassible during the spring, as it can be made so cheaply as to be within the means of any prosperous community. It can be made along the roadside, where it is wanted, by the hand process, which involves no outlay for plant and only a moderate degree of skill on the part of one head burner, in fact it does not need the experience or care required in making charcoal, which latter process it very much resembles. Where the roads are the heaviest it is frequently due to the presence of the very clay that makes the best ballast, and the material that would answer for this purpose probably occurs in abundance in every county north of the Missouri river. The road should be graded and crowned before surfacing it with burnt ballast, which should be put on to the depth of at least six inches, and deeper if the traffic is heavy. Such a road is entirely free from mud in wet weather, gives a smooth, hard surface and is easily repaired, as it wears out, by the addition of fresh material. The cost of macadamizing with burned gumbo varies according to the convenience of slack, wood or other cheap fuel.

Walks. Burnt gumbo makes a very good material for paths and walks as it is free from dust and mud. It also makes a pleasing contrast with the green landscape.

Deadening Floors. It has been used as a deadener or filling for the floors of buildings, for which it is especially adapted on account of its low weight and entire freedom from vermin.

MAKING BURNT CLAY BALLAST.

In the earlier practice of making burnt clay ballast, it was carried on exclusively by hand. This is still largely done where the amount to be made is moderate, as in the case for road purposes. Machinery was introduced later. There are several designs that are subject to patents, and some of the latest have proved very satisfactory in economy and reliability, showing a marked saving over hand work. The method of burning is identical in each case, but in the first instance the slack and gumbo are put on by casting or hand shovelling. While by machinery the clay is first dug loose and then spread on the pit by either an endless belt, carrying a plow and shovel device, or by small scrapers or large shovels that are manipulated by overhanging booms. Still later the slack is put on by machinery, and the burnt gumbo is shoveled into the gondolas or flat cars by steam shovels.

Hand Burning. In burning the clay by the hand method, the site is located along the railroad or country road, and a string of old railroad ties or cord wood is built in the form of a pyramid for a distance of 100 to 1,000 yards, in a straight line. This initial starting line of the pit should be about fifteen feet from the road so as to leave sufficient width for the laying of a track for the removal of the burnt clay. The wood is covered with a layer of slack to a depth of 2 to 4 inches, and then with a layer of 1 to 2 feet of gumbo or clay. This gumbo is cut from only one side of the "pit" and this face or vertical bank of the clay steadily retreats as the pit moves forward. On firing the wood, sufficient air enters the interstices between the clods of gumbo to carry on a slow combustion and to ignite the coal. The slack burns at such a slow rate that while it develops sufficient heat to convert the gumbo into a hard, strong, red material, it is not enough to slag, or vitrify, or over-burn it. A fresh layer of slack is thrown on the pit every day or so, to the depth of one or two inches, on which is cast 10 or 15 inches of fresh gumbo. Before slacking or adding a fresh coal, the face of the pit is raked over if necessary to regulate the uniformity of the burning, and check any spots that are burning too fast, or hasten any that are burning too slowly. A shoulder or slight ridge (that is the subject of a patent) is carried at the crest of the burning pit that acts slightly as a chimney, improving the draught and facilitating the uniformity of the burning. Extra quantities of slack are used during stormy weather, or if the gumbo is very wet, and the consumption of coal ranges from 10 to 20 per cent of the gumbo used. Slack is generally used, because of its very low cost, and the inability to get a very high heat that might over-burn the clay, besides giving a more uni-

form distribution of the heat than lump coal. The face of the pit for its entire length is fed uniformly with slack and clay, and grows or advances steadily on the one side, while it burns out, leaving a mass of cold, burned ballast on the other side. A temporary track that can be pushed sideways is laid on the one side, for the supply of slack, and another parallel track is laid along the burned outside of the pit, for the removal of the ballast. In hand-working the ballast is wheeled in barrows from the pit to the railroad cars. This is usually let out by contract at so much a car ($1.00 to $2.00.)

The face of the gumbo pit is usually 3 to 4 feet high. This makes a trench at the base of the pit which collects more or less water, especially in rainy weather, so that it should be on a slight grade, if possible, to run the water to one end, where it is pumped out by hand pumps, wind mills, or steam pumps, according to the amount to be handled. For burning gumbo for roads and walks the length of the pit ranges from 50 to 100 feet, according to the amount required. In burning for railway ballast the pits are made from 1,000 to 3,000 feet long. The cost of the burnt gumbo delivered on board cars is in the neighborhood of 50 cents a cubic yard when burned by hand, and from one-half to two-thirds of this when machinery is used. The hand system has the very attractive business feature of involving a very moderate capital, as there are no outlays for plant, beyond the moderate cost of a tool outfit, tracks and perhaps a few tents or shanties for the men. The capital is mainly required to meet the current expense which is principally for labor. The machine plants involve a much larger investment in plant, though this is quickly off-set by the reduced expense of manufacture, if the quantity required justifies a machine plant.

Burning Machinery. Two types of machines are employed to replace the labor of digging and casting the clay by hand, one of which employs an endless belt that is equipped with either plows or shovels, while the second type uses a small plow or scraper, which is operated by a rope from an overhanging boom. The latter type has been developed into a very efficient and reliable machine and has almost entirely done away with hand labor. The machine is carried on a car that runs on a temporary track along side the pit, and as it undermines the clay from beneath itself the track is pushed back, to permit of the slow, steady advance of the pit. When machines are employed the slack cars are rigged up with a light, overhanging platform, by which the pit is slacked directly from the car. A machine has been recently introduced in which the slacking of the face of the pit is done automatically with marked economy over hand work. The face of the pit is usually from 7 to 10 feet high in hand work, but can be carried 10 to

14 feet high in machine work. The pits are seldom carried deeper than 6 or 8 feet, on account of the trouble experienced from water seepage.

GUMBO CLAYS.

The class of clays that are adapted for burnt ballast are the very plastic, impure, black clays that are popularly known as "gumbo," and which are generally found in the low floodplain lands so characteristic of the rivers of north Missouri. Physically they are very fine-grained, extremely plastic, tenaceous clays, in fact the strongest of all clays. This is well shown by their very high tensile strength, which ranges from 270 to 410 pounds to the square inch of cross section, after moulding and thorough drying, whereas most clays range between 100 and 200 pounds. The gumbo clays shrink very heavily in air-drying, or from 8.0 to 10.0 per cent, which is the cause of their cracking and disintegrating, but only from 1.0 to 6.0 per cent in burning at a temperature necessary to make a good ballast, giving a total shrinkage of 9.0 to 12.0 per cent. They make a very plastic to extremely plastic paste, when mixed with from 22.0 to 25.0 per cent of water, and they have a specific gravity that ranges from 1.98 to 2.05, which is very low. This low density is due to the fact that they are the most recent of all clay deposits and have had no overlying formation to consolidate them. They are usually black in color, from the 2.0 to 5.0 per cent of vegetable matter which they contain, and which readily burns out. This organic matter is of considerable assistance in helping to break up the gumbo and aiding the burning. The gumbo clays seem to be free from sand. This, however, is more fancied than real, as like nearly all other clays, they are always more or less sandy, but the sand is usually so fine and uniformly distributed through them that it can only be detected by special examination. If contaminated by coarse sand, especially as sand streaks, it greatly interferes with its value for burnt ballast, from the weakness of the burnt material and the failure to "slack" or decrepitate into gravel.

The salient and vital feature of a successful ballast clay is that in drying and burning it should "slack" or fall to pieces, forming a mass of fragments that range from one-fourth inch to two inches in size. This property is found in all very strong or extremely plastic clays, which nearly always shrink so heavily as to cause them to crack or separate into small pieces. In the case of the gumbo clays this very eminent plasticity seem to be solely due to the extreme fineness of the grain (the fundamental element of plasticity). The granulation of the clay from shrinkage enables the gumbo to be added to the burning pit in large chunks or coarse sticky clods which quietly fall to pieces and

form an open, porous bed through which the air is able to enter to carry on a slow combustion and permits the ready and complete passage of the heat throughout the mass of granules.

Chemically the clays adapted for burnt ballast differ in no respect from common brick, paving-brick, sewerpipe, or other impure clays, and their peculiar value for burnt ballast is entirely a physical one. In composition they vary as follows:

	Per cent.
Silica	55.0 to 65.0
Alumina	15 0 to 20.0
Combined water	6.0 to 10 0
Iron sesquioxide	5.0 to 7 0
Lime	1.0 to 3.0
Magnesia	0.5 to 2 0
Alkalies	2.5 to 4 0

The total fluxing impurities range from 10.0 to 15.0 per cent. Incipient vitrification usually begins at 1,600° F., to 1,700°, complete vitrification at 1,750° to 1,850,° viscous at 1,900° to 2,000.° The lower the point of vitrification the better, on account of the less fuel required and the greater ease in burning.

OCCURRENCE OF THE BALLAST CLAYS.

Kinds of Deposits. The clays that have the above mentioned physical and chemical properties to adapt them for burnt ballast are mainly found in the low alluvial bottoms of the large streams in the northern half of the state. They are usually called "gumbo" by the farmers and are regarded almost as waste land, except for pasturage, as they are heavy, "cold," sour, very difficult to plow, and very slow in drying out in the spring. They represent the recent deposits of the adjoining rivers, during the flood stage. Where the overflowed bottom land is exposed to a current the silt deposited by the stream consits of more or less coarse sand, which makes very poor material for burnt ballast. It is the very fine silt of the quiet back waters that makes the ideal gumbo for ballast.

The glacial deposits on the higher elevations or prairie country sometimes possesses the extreme plasticity and impure composition that make excellent burnt ballast clays, and occasionally these are found in large enough bodies and of sufficient uniformity as to be adapted to this purpose. More frequently, however, the very strong glacial clays are not sufficiently uniform, as they more or less abruptly change into sandy clays, or are intermixed with sandy clays. The recent river sediment or "gumbo" is not altogether free from this trouble, but is much more liable to be than most glacial deposits, and to be less valuable for farm land.

The very tough residual clays south of the Missouri river, that are often of a bright red color, are frequently strong enough to fall into granules, if burned in a pit, and make an excellent quality of ballast. Although they are not usually found in such large bodies as the gumbo clays many of them can be successfully utilized and will be in the future. But there is generally an abundance of either chert or limestone south of the river, which being much more durable than burnt clay is usually preferred for ballast.

The very sticky and strong tallow clays that are so frequently found in the mining districts, especially in the southwestern lead and zinc region, are also well adapted for burnt ballast, but like the residual clays, are usually accompanied by an abundance of a better material in the shape of hard, durable chert, flint, or limestone. In describing the detailed occurrences of clays suitable for burnt ballast, the residual and tallow clays will not be further mentioned for this reason, especially as the former are referred to under brick clays.

Missouri River Counties. The counties that border on the Missouri river have more or less gumbo, though in variable amounts. In some of the counties, the floodplain of the river is from five to ten miles wide, in which case the best gumbo is to be found near the bluffs, and rarely near the river. Extensive deposits along this stream which have been utilized for this purpose are at La Pierre, in Holt county, on the Kansas City, St. Joseph and Council Bluffs railroad, and at Norborne, in Carroll county, on the Wabash railroad.

Mississippi River Counties are also more or less rich in gumbo deposits, especially the extreme southeastern ones, as Scott, Mississippi Pemiscot, Dunklin and New Madrid, while the gumbo has been utilized at St. Peter, in St. Charles county, for the Wabash railroad.

The floodplain adjoining other streams have more or less workable deposits of gumbo, the Nodaway, Platte, Grand and its larger forks, Chariton and its larger tributaries, Salt, North and South forks of the Fabins, Wyaconda and the Little Fox. In the case of the smaller rivers the wide flood-plains in which the gumbo is found are usually near the mouths of the streams.

In the counties north of the Missouri river, which are covered by the glacial drift, there are deposits of greater or less extent in the higher prairie country, which have been worked at Kearney, in Clay county, and at Jonesburg, in Montgomery county.

The gumbo deposits and the strong glacial clays of the prairie are very much thicker than it is profitable to use for burnt ballast. On account of their fine, close character, they are impervious to water, so that the pit retains the rain and drainage water. It does not usually

pay, therefore, to excavate lower than 6 to 8 feet below the surface, as the water is too troublesome and the risk of flooding too great. The gumbo is usually much thicker than this and along the Missouri and Mississippi rivers often 20 to 60 feet thick. The upland prairie clays (glacial) also sometimes exceed 50 feet in thickness.

BURNT BALLAST PITS.

Burnt ballast is being made at number of places.

La Pierre. This plant is in Holt county. It was started in 1892 by the Western Clay Ballast Co., with headquarters at Cameron, Mo. It is on the Missouri river and the gumbo is being worked to the depth of 6 feet in two pits each about 2,000 feet long.

Amity. In DeKalb county a plant has been operated on the Chicago, Rock Island and Pacific railroad by the Western Clay Ballast Co. since 1891. It obtains the clay largely by widening the cuts along the railroad, which is glacial clay.

Easton. The plant in Buchanan county, on the Hannibal and St. Joseph railroad, is operated by the Davy Clay Ballast Co., of Kenosha, Wisconsin. It is using a glacial clay.

Kearney. In Clay county, on the Hannibal and St. Joseph railroad, is a plant operated by the Davy Clay Ballast Co. There is one pit 2,000 feet long which is operated by a machine outfit. A glacial clay on the prairie is utilized.

Norborne. In Carroll county, on the Wabash and the Atchison, Topeka and Santa Fe railroads, is a plant that was started by the Davy Clay Ballast Co., in 1891. It has one pit 2,400 feet long along the last mentioned road and two pits each half a mile long on the Wabash road, with which latter system the company has a contract to supply 250,000 cubic yards. The plant is operated by machinery, and the quality of the gumbo is unusually favorable. It is near the Missouri river.

A sample gave the following results: Color gray to drab, with abundant brown spots of iron staining. Texture very soft, very sticky, and highly plastic, drying to a hard, very tough, mass, very fine-grained and uniform. Taste, very fat. Slacked readily and completely to one-eighth to one-twentieth of an inch granules. Pyrite was not noticeable; small white specks of carbonate of lime occurred occasionally; hydrochloric acid caused copious effervescence in the cold, and gave a deep yellow solution from carbonate of iron. When ground to 20-mesh and mixed with 23.0 per cent of water it made a very plastic paste that shrunk 9.6 per cent on drying and 1.4 per cent when vitrified, giving a total shrinkage of 11.0 per cent. The air-dried

mud had an average tensile strength of 380, and a maximum strength of 400 pounds to the square inch. Incipient vitrification occurred at 1,600° F., complete at 1,750,° and viscous above 1,900°. It burned to a compact, strong, body of salmon color. It required to be dried and heated slowly to prevent cracking and to be very slowly dried to prevent warping.

A chemical analysis gave the following results:

	Per cent.
Silica	54.90
Alumina	18.08
Combined water and carbonic acid	6.90
Moisture	6.72
Iron sesquioxide	6.03
Lime	2.88
Magnesia	1 10
Alkalies	3.40
Total	99 95
Total fluxing impurities	13.41
Specific gravity	2.01

New Cambria. The plant in Macon county is on the Hannibal and St. Joseph railroad. It is operated by the Davy Clay Ballast Co., which is using gumbo from along the Chariton river. There is one pit, about 2,000 feet long, that was started in 1892. A machine outfit is used.

Clifton. In Randolph county, on the Wabash railroad, a plant was started in 1892, by the Davy Clay Ballast Co., which has a capacity of 150,000 cubic yards a year. There are two pits, each about 2,000 feet long, which are operated by machinery. The deposit is on the edge of the Chariton river.

A sample of the clay gave the following results: Color dark slate, fully specked with brown iron stains. Texture very soft, very sticky, tough and highly plastic in the pit; drying to a hard, very strong mass, very fine-grained and uniform. Taste, very fat. Slacked slowly but completely to one-tenth to one-fourth of an inch grains. Pyrite was not visible. When ground to 20-mesh and mixed with 23.0 per cent of water it made a very plastic paste that shrunk 8.5 per cent in drying and 1.5 per cent when vitrified, giving a total shrinkage of 10.0 per cent. The air-dried mud had an average tensile strength of 319, and a maximum of 380 pounds to the square inch. Incipient vitrification occurred at 1,600° F., complete at 1,750°, and viscous above 1,900°. It burned to a strong, compact, body of a salmon color. It required to be slowly heated and dried to prevent cracking, and very slowly dried to prevent warping.

A chemical analysis gave the following results:

	Per cent.
Silica	62.80
Alumina	17.22
Combined water	7.82
Moisture	2.06
Iron sesquioxide	5.21
Lime	0 98
Magnesia	0.78
Alkalies	3.68
Total	100.70
Total fluxers	10.60
Specific gravity	1.98

Jonesburg. A plant on the Wabash railroad, in Montgomery county, was operated by the Western Clay Ballast Co. It worked a glacial clay that lies in a slight swail of the prairie, but it has not proved satisfactory in quality. It began operations in 1890, with a pit about 1,500 feet long, and has not been operated since. It was a hand plant.

Elm Point. In St. Charles county is a large plant, on the Wabash railroad, that is operated by the Chicago Burnt Clay Ballast Co., an off-shoot of the Western Clay Ballast Co. It was started in 1891 and was operated by hand, having two pits, 1,200 feet long. It is on the edge of the Mississippi river floodplain and the gumbo makes a superior quality of ballast. Being below the high water mark of the river it is liable to be drowned. In 1891, 165,000 cubic yards were produced, but it was shut down by the floods in 1892; it made 60,000 cubic yards in 1893, when the floods again curtailed the season.

A sample of the clay gave the following results: Color very dark slate, almost black (dry). Texture, very soft, very sticky and highly plastic in the field, drying to a very tough, hard mass, fine-grained and uniform. Taste, very fat. Slacked readily and completely to one-fifteenth to one-eighth of an inch grains. Pyrite was not noticeable; contained white concretions of carbonate of lime from one-sixteenth to one-half of an inch in diameter; a few molluscan shells occurred occasionally; hydrochloric acid caused a slight effervescence in the cold. When crushed to 20-mesh and mixed with 23.0 per cent of water it made a very plastic paste that shrunk 8.0 per cent in drying and 1.5 per cent in burning, giving a total shrinkage of 9.5 per cent. The dried mud had an average tensile strength of 273, and a maximum strength of 323 pounds to the square inch. Incipient vitrification occurred at 1,650° F., complete at 1,800°, and viscous above 1,950°.

the water to pass through it in the wet weather, and is sufficiently porous and open to remain damp throughout the dry weather. Such soils are called loams and they often make the best kind of building brick, and occasionally draintiles, but are seldom satisfactory for other purposes. If in the vicinity of railroads the cuts exposed frequently give satisfactory sections of the underlying materials, especially after heavy rains, when freshly exposed faces can often be seen. If it is an old railroad so that the banks are well settled and covered with washings, it may be necessary to pick through the loose overlying washings to get to the undisturbed clay.

Very strong evidence of underlying fat clays is often seen in the sloughing of banks which, according to the distance and angle through which it slides or moves, gives an excellent idea of the thickness as well as the existence of a fat strong clay deposit without its ever having been seen. Plastic fireclays and potters' clays are frequently found without ever being exposed to view by this evidence of sloughing in natural or artificial banks, where there is much of a slope. When streams with strong currents flow over beds of very fat or very plastic clay, the clay is usually sharply and clearly exposed to view, as it readily resists the erosion of water. The evidence of wells, cellars, fences and telegraph post-holes are all worthy of careful study when the evidence is reasonably fresh, and such occasional evidence as canals and sewers are of similar high value when obtainable in actual sections, or as freshly made dumps.

Clays cannot be discovered by "float" except the flint clays, as they are too soft to stand weathering and erosion, but concurrent evidence can often be utilized, as in southeastern and southern Missouri where the kaolin is intimately associated with a peculiar pink and white chert that is different from the ordinary kind found throughout the district. Such float, when followed up by test-pits, frequently leads to the discovery of valuable deposits of kaolin that may be several yards beneath the surface. The flint clays, when they come to the surface can usually be found by small sharp angular fragments of flint clay, which makes a soil that sustains a very meagre growth of vegetation.

The presence of excessive water, especially if prolonged for sometime after a rain, is strong evidence of underlying clay, where there is not much grade. If the underlying clays are very plastic the surface waters scarcely permeate through them, and if there is sufficient overlying soil to sustain vegetation, they become more or less swampy, at least during the wet season, though there may be a decided slope. In many of the north Missouri prairies where the so-called "hard pan," or tough glacial clay comes near the surface, the lands are wet, though often

favored with slopes that would usually readily drain the ground. Such clays are nearly impervious to percolating water.

Fireclays, potters' clays and shales often exhibit yellow, brown, or red iron-stained faces on the weathered outcrop that would seem to render the clay valueless for many purposes, from the apparent excessive amount of iron present. It should be remembered, however, that a very small amount of iron can stain a very large surface, and it is therefore liable to greatly mislead as to the amount of iron present in the clay judged by the weathered face only. Occasionally the clay contains an amount of iron which if disseminated throughout the clay would be disastrous; but as seams, nodules, or concretions, it can often be picked out at little or no expense, and thus render the clay quite valuable. One of the best fireclay deposits in Missouri, which is used for the very exacting demands of glass-pots, presents a very unattractive appearance from its apparent excessive amount of iron that would cause it to be at once condemned by superficial observers. The condition of the iron, however, is such as to render it very conspicuous but it is easily eliminated by washing, after which an excellent quality of pot clay is obtained.

Boring for Clays. The earth-augur is a very valuable aid to the clay prospector when the clays are at or near the surface. If gravel, bowlders or other hard material do not interfere, the augur system of prospecting can be carried on to depths of 20 to 25 feet with ease and rapidity, and to depths of 40 to 50 feet when provided with a more substantial equipment. A two-inch bit is usually employed which is most conveniently operated by using gas-pipe that is lengthened by screwing on additional joints from time to time as the greater depths are obtained. It is a very rapid and cheap method of gaining information to moderate depths, if no rock interferes, and furnishes samples that are usually sufficient for preliminary tests. The outfit is so light, and portable as to be readily packed around by a man and it involves a very small outlay for tools and labor. Where larger samples are desired 4- to 8-inch augurs can be employed, but such large bits require at least two men to operate and they take considerable more time; but samples of several hundred pounds weight can be secured, thus enabling larger and more satisfactory tests to be made.

The augur system of boring can be used in soft shales and plastic fireclays to a depth of 15 to 20 feet, though with more or less difficulty. If the material is too hard and tough, it will be necessary to use drop-drills, which have no practical limit; but the material is obtained in the very objectionable form of "sludge" or a soft mud, unless the hole is cased with tubing, the sample often being contaminated by droppings

from the upper part of the hole. The drop-drilling method can be carried through material of any hardness and with bits from 3 to 12 inches in diameter, but to give reliable information, the hole should be cased to prevent the caving in of material from above, which adds considerably to the expense and time required. A drop-drilling outfit is heavy and expensive, and requires from two to four experienced men, while the cost of the drilling ranges from $1.00 to $5.00 a lineal foot.

The diamond drill method of prospecting, which is such a rapid and favorite one in rock formations is a failure in ordinary clays, from the impossibility of keeping the core-barrel from choking. It can be used for flint clays and lean or hard shales, however, though it will not give a satisfactory core, but a passage can be maintained for the water through the core-barrel, and the sludge is collected at the overflow pipe and as more or less broken fragments in the core barrel. It is an expensive outfit that requires two experienced men and a team of horses, while the cost of drilling a hole one to two inches in diameter ranges from 75 cents to $3.00 a lineal foot.

Test-Pits. The test-pit method of prospecting for clays, or sinking small shafts or prospect holes is the most satisfactory method of arriving at the thickness and quality of underlying clays, as it permits personal inspection of the deposit and the removal of samples of unlimited size. When carried on by a successful specialist it is economical, rapid and safe. By using a very short handled, small sharp pick spade and making the hole 30 to 40 inches in diameter (the narrower the safer), with one man below digging and a second man above hoisting out the dirt and water, from 10 to 40 feet can be sunk in a day, according to the character of the material, if no timbering is required. In some clays a pit or hole 40 inches in diameter will stand from ten to twelve days, thus enabling one to get down and take out samples before it gets dangerous, from the dropping off of pieces from the sides of the pit. The more sandy the clay, usually, the greater the safety in sinking without risk of caving or dropping off, if not timbered. With very strong plastic clays there is a great risk from chunks falling off without warning which renders it very dangerous for the man below. The secret of success in such work is to keep the pit very small, or 30 inches in diameter, if possible, selecting the dry season, when the ground is free from water and pushing the work very fast so as to quickly get down to the deposit; and to rapidly inspect and obtain samples before the ground begins to work off. This necessitates small sharp tools and experience, when the work is safe and rapid if in the hands of an ex-

pert; but it is dangerous, uncertain and expensive, if attempted by a novice. As the dry season is usually during the hot weather, or for only four months, there is one serious trouble in sinking such small pits, especially if over 15 feet in depth, which arises from the difficulty in ventilating them. If the ground safely permits of this excellent method, however, this difficulty can be overcome by throwing fresh air down to the bottom of the pit by means of a small fan and a canvass air pipe, or by the cheaper though less efficient method of wind sails, which latter are only reliable or satisfactory when there is a good breeze.

If the ground is very wet, jointy, or heavy, it is necessary to timber the pit in order to prevent it from caving in. If the pit is solely for prospecting and there is no intention of subsequently using it the cheapest method is to timber it with circular curbs, which are comparatively inexpensive, yet are strong enough for temporary service, if used promptly before the ground gets weakened by partial caving. If the clay is very heavy, especially if it swells, the circular curbs are not strong enough, and in such cases square timbering is necessary, in which heavy lagging boards on the outside are backed by strong, square cribs which can be made of such size and used so frequently as to hold in the earth.

CHAPTER XVIII.

METHODS OF SAMPLING AND ANALYSING CLAYS.

SAMPLING.

Great care was taken in the collection of the samples of the Missouri clays which has resulted in obtaining a series of tests and analyses that represent the average character of the clay banks tested. This is a matter that is usually seriously overlooked, and the analyses that are published of most clays and shales are unreliable, and frequently are grossly misleading, because they are the analyses of picked and not average samples.

The collection of the samples is too frequently entrusted to those who either fail to appreciate the importance and difficulties of sampling, or to those who have too much at stake because affecting self-interest. Practical men do not insist upon the care that is necessary to obtain a reliable sample, while scientists have frequently been grossly careless in failing to appreciate the necessity of this primary requisite. In both cases a small fragment of clay is usually selected which at best is liable to be an off-hand sample that seldom represents the average of the bank, except in clays that are very uniform. While there are a few clay seams that are so uniform that a small piece will represent the entire clay bank, such cases are extremely rare and such sampling is inexcusable.

In the collection of the Missouri samples, which was done chiefly by Messrs. Leo. Gluck and G. E. Ladd, 50 to 60 pounds were taken from each face or bank of clay which was obtained with a pick or pointed hammer, and shipped direct from the field to the laboratory. The field samples were allowed to gently dry on top of a boiler before being crushed or sampled. The pieces were broken down to the size of pecan nuts, and then ground to pass through a 20-mesh sieve (400 holes to the square inch). The sample was then thoroughly mixed, and a small batch of about one and one half pounds, was dipped from, all for samples, which was required to pass through a 100 mesh sieve (100,000 holes to the square inch).

CHEMICAL ANALYSES OF THE CLAYS.

The analyses of the clays were made by Messrs. A. E. Woodward, J. D. Robertson and Otto Rissman. Mr. Woodward was the chemist to the Survey, and was a student under Dr. Brown at the Massachusetts Institute of Technology. Upon his death he was succeeded by J. D. Robertson, a student under Prof. Wm. B. Potter. Mr. Rissman is the chemist to the St. Louis Sampling and Testing Works. The methods used by Mr. Woodward and by Mr. Rissman are herewith described in full.

METHODS ADOPTED BY WOODWARD AND ROBERTSON.

Silica. One gram of clay was fused with 10 grams of a mixture of K_2CO_3, Na_2CO_3, and a little KNO_3. When fusion was complete the mass was cooled and dissolved with hot water, the crucible being heated with HCl, and its washings added to the solution. The solution is then acidified with HCl, evaporated to dryness, and gently ignited to render the SiO_2 insoluble. The mass was then treated with 10 c. c. concentrated HCl, and 50 c. c. H_2O, and the whole digested on the water bath for 15 minutes. 50 c. c. of H_2O were then added, the solution filtered and the filter washed with hot water, dried, ignited, and weighed. It was then treated with HFl, and a few drops of H_2SO_4, evaporated to dryness, ignited and weighed; the difference in the two weights being the SiO_2.

Alumina and Iron. Any residue was added to the filtrate from the silica. The filtrate was heated to boiling, H_4NOH having been added to faint alkaline reaction, filtered on an ashless filter, and washed with hot water until no traces of Cl could be seen in the washings. The precipitate was dried, ignited, moistened with HNO_3, and again dried, ignited, and weighed as Al_2O_3 and Fe_2O_3. The ignited mass was then fused with $KHSO_4$, dissolved in 100 c. c. water, with a little H_2SO_4, reduced by metallic zinc, and titrated with a standard solution of $KMnO_4$. It was calculated as Fe_2O_3, and subtracted from the weight of the Al_2O_3 and Fe_2O_3, to obtain the weight of the Al_2O_3,

Lime. The filtrate and washings from the precipitate of the combined oxides were evaporated to 300 c. c., 10 c. c. NH_4OH added. 20 c. c. of a standard solution of $(NH_4)_2C_2O_4$ (made by dissolving 40 grams of the crystalized salt in one litre of water) were then added both the solution and precipitate being boiled. The CaC_2O_4 separated out in 30 minutes, and was filtered immediately, as otherwise magnesia would be precipitated also. The precipitate was washed thoroughly with hot water, dried, ignited with a blast lamp for ten minutes, and weighed as CaO.

Magnesia. To the filtrate and washings were added 5 c. c. NH_4OH and 20 c. c. of a standard solution of microcosmic salt, NH_4NaHPO_4, (100 grams to one litre of water.) It was stirred well and allowed to stand over night. It was then filtered through an ashless filter, washed with dilute solution of ammonia (Sp. Gr. 0.80), dryed and ignited carefully, the paper being burned before the addition of the bulk of the precipitate in the platinum crucible. The precipitate was treated with a drop a HNO_3, evaporated over the blast lamp, and weighed as $Mg_2P_2O_7$.

Alkalies. The alkalies were determined by the method described by J. Lawrence Smith. One gram of the clay was rubbed thoroughly with an equal weight of NH_4Cl in a mortar, and 15 grams of pure $CaCO_3$ added, and thoroughly mixed. The whole was placed in a capacious platinum crucible, and heated gently until all fumes of NH_4Cl ceased to come off; then the base of the crucible was kept at a dull red heat for one hour. At the end of this time the mass was found sintered together, and was easily detached from the crucible. It was transferred to a platinum dish, the crucible being washed into the dish. The mass was digested for half an hour on a water bath, filtered, and the residue thoroughly washed. The filtrate and washings were evaporated to about 40 c. c. and a few drops of NH_4, and about two grams of $(NH_4)_2CO_3$ were added. The whole was heated, filtered, and the filitrate evaporated carefully. A few drops of $(NH_4)_2CO_3$ were added, and if there was any precipitate, it was filtered off. The filitrate was put into a weighed platinum crucible, and evaporated to dryness. It was heated carefully, to drive off ammonia salts, and weighed as KCl and NaCl. These were then calculated as K_2O and reported as alkalies, except when they were to be separately determined.

Moisture and Combined Water. The moisture was determined by drying one gram of the clay at 105°C. for one hour. The combined water or ignition loss was determined by the preceding dry portion over a blast lamp for fifteen minutes.

METHODS ADOPTED BY RISSMANN.

Moisture. The clay was first dried at a temperature of 105° to 110° C. from one to one and one-half hours.

Combined Water. One gram of the dried clay was weighed in a platinum cruicible and heated over a blast lamp for half an hour; the difference in weight was the loss by ignition.

Silica. One gram of finely pulverized clay was fused with 10 grams of $NaCO_3$; the fused mass was dissolved in water, acidulated with HCl and a few drops of HNO_3, and evaporated to dryness. It was moist-

ened with HCl, again evaporated and dryed at 140° C. for an hour and a half. 100 c. c. of water and and a little HCl were then added. The liquid was boiled, filtered and washed with hot water. Then ignited and the precipitate weighed, as silica plus impurities. Ignited in a platinum crucible, with pure HF and a few drops of H_2SO_4 and weighed again. The loss represented silica.

Alumina and Iron. The impurities, which consist of a little alumina and iron were treated by themselves. The filtrate occupied about 200 c. c. Ammonia in slight excess was added to precipitate the iron and alumina and boiled until the smelt of ammonia was gone. It was then filtered and washed with hot water and ignited. The iron and alumina were weighed as oxides. This operation was repeated. The iron and alumina fused with about 5 grams of $NaCO_3$. The fused mass was dissolved with water, acidulated with HCl, brought up to boiling; $SnCl_2$ was added, drop by drop, until colorless, and allowed to cool. $HgCl_2$ was added in excess and titrated with standard solution of K_2CrO_4, $K_3Fe\ Cy_6$ being used as the indicator. The Fe_2O_3 was calculated, the titrate being deduced from the weight of Fe_2O_3, plus Al_2O_3, when the difference was Al_2O_3.

Lime. The two filtrates from the iron and alumina were combined, boiled down to about 200 c. c., made slightly ammonical. $(NH_4)_2C_2O_4$ was added to slight excess, boiled for ten minutes and allowed to settle in a warm place. It was then filtered, washed with hot water, ignited, a few drops of H_2SO_4 added to convert into sulphate, and after excess of SO_3 was driven off, weighed as sulphate of lime; from this CaO was calculated.

Magnesia. The filtrate from the lime was evaporated down to about 200 c. c., allowed to become perfectly cool and made strongly ammoniacal; the magnesia was precipitated with microcosmic salt. It stood for about 12 hours, was then filtered, washed with ammoniacal water, ignited, and weighed as MgP_2O_7, and from this the MgO was calculated.

Alkalies. One gram of fine clay was intimately mixed with one gram of pure NH_4Cl, and 8 grams precipitated $CaCO_3$, and heated to a dull redness in a high covered platinum crucible for one hour. The mass sintered together so that on treating with water it completely slacked and a fine residue was left, while the alkalies passed into solution as chlorides. The filtrate was filtered, washed to disappearance of chlorine re-action, and evaporated in large platinum dish to small bulk. The lime present was precipitated by addition of $(NH_4)_2CO_3$ and filtered. The filtrate was evaporated in a platinum dish to complete dryness, and the fumes of ammonium salts driven off. It was

taken up in a little water, a little $(NH_4)_2CO_3$ added to precipitate the trace of lime remaining, and filtered. The filtrate was evaporated to dryness and the dish heated to dull redness until all ammoniacal salts were driven off. It was weighed and dissolved in small amounts of water and transferred to a porcelain dish, a calculated amount of $PtCl_4$ was added, then evaporated carefully until the residue was pasty, 75.0 per cent alcohol was added and then filtered. The filter paper was allowed to dry; the K_2PtCl_6 dissolved out with boiling water into a weighed platinum dish, evaporated to dryness and allowed to dry for one hour at 130° C. The weight gave the K_2PtCl_6 in one gram of clay.

Specific Gravity. Specific gravity was determined with a Jolly balance. If the clay was very soft, it was first weighed, then dipped in parafine, weighed again, and finally weighed in water, and the specific gravity of clay found after deducting the specific gravity of the parafine.

CHAPTER XIX.

TABLES OF ANALYSES AND TESTS.

CHEMICAL ANALYSES OF THE MISSOURI CLAYS.

The following tabulation of the chemical analyses and physical tests of the Missouri clays is arranged alphabetically by counties. It is the bringing together of all the clays and shales that have been tested in the preparation of the report. The detailed occurrences and description of these clays are found under their proper heads in the various parts of the report.

For the details as to the method of collecting samples and making the analyses, reference is made to the preceding chapter.

Chemical Analyses of Mis-

Running No.		Moisture, HO_2	Combined water, H_2O	Silica, SiO_2	Alumina, Al_2O_3	Total non-detrimentals	Ferric oxide, Fe_2O_3	Lime, CaO	Magnesia, MgO
	AUDRAIN COUNTY—								
4	Fire clay, Mexico	......	10.56	55.12	30.71	96.39	1.51	0.54	Tr.
5	Fire clay, Mexico	.....	11.48	51.40	33.61	96.52	1.26	0.71	Tr.
6	Fire clay, Vandalia	......	12.68	53.77	30.90	97.35	1.74	0.39	0.32
7	Fire clay (washed), Vandalia	......	12.34	52.66	32.52	97.52	1.42	0.28	0.22
	BARTON COUNTY—								
8	Potters', Waltmans, 4 miles south Lamar	.....	7.42	65.32	22.63	95.37	1.81	0.25	0.67
9	Potters', Wear mine, Minden	......	11.58	50.94	24.24	86.76	7.18	0.95	1.60
	BATES COUNTY—								
10	Shale, Foster	....	7.32	55.96	20.62	83.90	8.12	1.91	1.96
	BOLLINGER COUNTY—								
11	Kaolin, Glen Allen	......	7.04	72.30	18.94	98.28	0.40	0.68	0.39
	BOONE COUNTY—								
12	Fire clay, Fay's bank, Columbia	1.66	8.14	61.22	25.17	96.19	1.47	0.31	Tr.
	CALLAWAY COUNTY—								
13	Fire clay, Fulton	.....	12.76	47.30	37.54	97.60	1.48	0.57	......
15	Fire clay, New Bloomfield	......	12.48	48.60	35.65	96.73	1.95	0.51	0.26
16	Potters', Moore place, near Guthrie	.....	13.58	48.92	32.90	95.40	3.10	0.40	0.37
17	Potters', washed, Moore place, near Guthrie	......	13.88	47.13	34.96	95.99	2.92	0.37	0.32
	CAPE GIRARDEAU COUNTY—								
18	Kaolin, Brook's land, Cape Girardeau	....	2.74	91.05	5.01	98.80	0.69	0.24	0.22
	CARROLL COUNTY—								
19	Gumbo, Davy C. Ballast Co., Norborne	6.72	6.90	54.90	18.08	86.55	6.03	2.88	1.10
	CARTER COUNTY—								
20	Kaolin, washed, Mo. L. & M. Co., n'r Chilton	.....	6.16	73.82	18.16	98.14	1.32	Tr.	0.21
	CASS COUNTY—								
21	Potters', Harrisonville	.....	7.53	63.93	19.78	91.19	3.69	0.53	1.21
22	Potters', washed, Harrisonville	......	7.42	64.62	19.96	92.02	2.91	0.44	1.81
	CHRISTIAN COUNTY—								
23	Shale, Billings	......	7.05	63.11	23.11	93.27	1.79	0.42	0.70
	COLE COUNTY—								
24	Brick clay, Jefferson City	......	3.17	74.39	12.03	89.59	4.06	1.50	1.52
	COOPER COUNTY—								
25	Brick clay, Boonville	.....	6.71	81.11	11.62	89.44	3.90	2.37	1.47
26	Shale, near Boonville	.....	6.94	53.24	23.62	83.80	9.02	1.17	1.41

souri Clays and Shales.

Alkalies ...... K_2O Na_2O	Miscellaneous......	Total detrimentals.	Grand total.....	No samples tested	Specific gravity...	Size of grains......	Vitrification—(degrees Fahrenheit). Incipient..	Complete..	Viscous....	Color of burned ware............	Purpose used.....	Analyst............	Running No.........
1.87	....	8 42	99.81	...	......	C.	......	......	......	Buff	Fire brick	Rissmann..	4
1.28	....	8.25	99.77	3	2.46	C.	2,200	2,400	2,600	"	"	Woodward	5
0.49	....	2.94	100.29	3	2.43	V.F	2,300	2,500	2,700	"	"	"	6
0.52	....	2.44	99 96	..	....	V.F.	2,300	2,500	2,700	"	"	"	7
1.72	....	4 45	99 82	3	2.46	Fine	2,000	2,200	2,400	"	Stonew .	Rissmann..	8
3.60	. ...	13.33	100 09	3	2.54	F.	1,700	1,650	2,000	Red.	Not wkd.	"	9
3.34	....	15.83	99.23	3	2.25	F.	1,600	1,800	2,000	Red.	"	"	10
0.42	....	1 89	100.17	8	1.89	V.F.	2,200	2,500	2,600	Wh.	White W.	"	11
1.88	....	3 66	99.85	3	2.49	C.	2,050	2,250	2,450	Gray	Stonew ..	"	12
0 50	....	2.55	100.15	3	2.44	C.	2,300	2,500	2,700	"	Fire brick	"	13
0.49	... .	3 21	99 94	8	2.27	V.F.	2,200	2,400	2,600	"	Not wkd.	"	15
0.82	....	4.69	100 09	4	2 13	V.F.	1,900	2,100	2,300	Brn.	Stonew...	"	16
0.52	... .	3.76	100.12	..	.....	V.F.	2,000	2,200	2,400	"	"	"	17
0.12	....	1.27	100 07	3	2.02	F.	2,300	2,600	2,700	.....	White W.	"	18
3.40	....	13.41	99 95	3	2.01	V.F.	1,600	1,750	1,900	Red.	R'y bal ..	"	19
0.24	....	1.77	99 91	....		V.F	2,300	2,500	2,600	Wh .	Not wkd.	"	20
3.40	....	8.83	100.02	4	2 34	F to C	1,700	1,900	2,100	Brn.	Not wkd.	"	21
3.25	....	7.90	99 90	..	.....	F.	1,750	1,950	2,150	"	"	"	22
3.71	....	6.62	99.89	4	2.16	F.	2,000	2,200	2,400	Buff.	Terra cot.	"	23
3 01	....	10.09	99.68	3	2 09	C.	2,000	2,200	2,300	Red.	Red brick	"	24
3.14	....	10.88	100 32	3	2.20	F.	2,000	2,200	2,300	Red.	Red brick	"	25
4.38	....	15.98	99.78	5	2.89	F to C	1,500	1,700	1,900	"	Not wkd.	"	26

CHEMICAL ANALYSES OF MISSOURI

Running No.		Moisture, HO_3	Combined water, H_2O	Silica, SiO_2	Alumina Al_2O_3	Total non-detrimentals	Ferric oxide, Fe_2O_3	Lime, CaO	Magnesia, MgO
	CRAWFORD COUNTY—								
27	Flint clay, Leasburg	....	14.94	43.82	38 24	97.00	0.23	1.93	......
28	Flint clay, Sankey mine	1.45	10.43	50.18	33.03	95 07	2.31	0.24	0.68
	FRANKLIN COUNTY—								
29	Flint clay, Dry Branch	.....	14.00	42.60	41.88	98.48	0.62	0.28	0.20
30	Ball clay, Union	.....	13.84	44.14	39 86	97.84	0.46	0.77	0 46
	GASCONADE COUNTY—								
31	Flint clay, Drake	......	14.15	40.50	43 22	97.87	0.31	1.11	Tr.
32	Flint clay, Owensville	0 42	12.20	44.70	35.92	93.24	3.85	3.00	0 21
	HENRY COUNTY—								
35	Potters' clay, Calhoun	1.01	5.27	71.94	17.60	94 81	2.35	0.62	0.56
36	Potters' clay, Dunlap pit, Clinton	1 04	5 95	67.49	21.11	94.55	2.45	0.17	0.63
37	Potters' clay, Frowein pit, Clinton	1.20	5 50	64.97	22.64	93.11	3.28	0.61	0.80
38	Potters' clay, Grant farm, Clinton	......	8.74	59.33	25.09	91.16	4.09	0.84	1.17
39	Shale, Grant farm Clinton	1 48	8 66	52.70	26.86	88.20	4.49	0.57	0.68
40	Shale, Town creek, Clinton	1.41	8.90	54.69	25.96	89.55	4.97	0.18	0.15
41	Potters' clay, Mo. Clay Co., Deepwater.	0.49	8.69	74.02	15 26	92 97	2.02	0 48	0.51
42	Potters' clay, Mo. Clay Co., Deepwater	2 02	4.76	72.86	12.99	90.61	2.95	0.35	0.47
43	Shale, Mo. Clay Co., Deepwater	0.52	4.62	68 54	18.49	91 65	3.38	1.03	0.88
44	Pipe clay, Dickey Sewerpipe Co., Deepw'tr	1 05	6 32	60.12	21.35	87.79	7.06	0.52	1.08
45	Potters' clay, Gilkerson ford	0.46	0.86	86.98	14.72	95 57	2.48	0 65	0.58
46	Shale, Gilkerson ford	1.08	8.88	55.02	24 38	88.28	5 79	0.58	1.50
47	Brick clay. Gilkerson ford	1.61	4.74	74.72	13 72	93 18	4.32	0 50	1.08
48	Brick clay, Hartwell	1.85	5 30	60.93	21.51	87.74	6.72	0.52	0.88
49	Potters 'clay, Fields creek	1.25	8.60	55.39	25.79	89.78	4 83	0.53	0.31
50	Shale, Fields creek	......	11 95	55.44	22.88	90.37	5.86	0.38	0.69
51	Shale, Vickey land	......	6.03	59.06	23.05	88.14	7.31	0.46	0.86
	HOWELL COUNTY—								
53	Kaolin (washed), Macy place, Stirling	......	11.43	57.75	27.60	96.78	2.09	0 24	0.31
54	Kaolin, Yates bank, West Plains	......	12.86	60 55	24.77	97.98	0.84	0.25	0.41
	IRON COUNTY—								
55	Residual, Tiptop, in Ry cut	.....	2.72	90 05	4 63	97.40	2 31	Tr.	Tr.
	JACKSON COUNTY—								
57	Shale, D. B. & T. Co., Kansas City	...	6.00	54.80	23.73	84.53	8.67	0.64	2.23
58	Shale, North Bluff, Kansas City	.....	8.45	55.75	21.16	85 36	5.69	3.25	2.84
59	Brick clay, Kansas City	......	6.42	72.00	11.97	90.39	3.51	1 80	1.35
60	Brick clay, Kansas City	.....	2.70	74.60	12 26	89 56	3.87	1.69	1.12

CLAYS AND SHALES—Continued.

Alkalies ...... K_2O Na_2O	Miscellaneous	Total detrimentals.	Grand total	No. samples tested	Specific gravity ...	Size of Grains	Vitrification—(degrees Fahrenheit) Incipient ...	Complete ..	Viscous	Color of burned ware	Purpose used	Analyst	Running No.........
0.73	....	2.89	94.89	3	2.35	V.F.	2,350	2,700	2,700	Wh.	Fire brick	Rissmann .	27
2 06	....	5 29	100 36	3	2.10	C.	2,100	2,300	2,500	Gray	Not wkd.	"	28
0.54	....	1.61	100 12	4	2 43	V.F.	2,350	2,700	2,700	Wh.	Fire brick	Woodward	29
0.76	....	2.45	100.29	3	1 98	F.	2,200	2,400	2,650	"	....	"	30
0.51	....	2.93	99.80	3	2 35	V.F.	2,300	2,500	2,750	Gray	Not wkd.	"	31
0.29	....	6 85	100.09	..	.....	F.	2,050	2,200	2,250	B-R.	"	"	32
1.51	....	5 04	99.85	4	2.34	V.F.	2,100	2,300	2,500	Buff.	Stonew ..	"	35
2.83	....	6.06	100.63	3	2.23	V.F.	2,000	2,200	2,400	Gr-B	"	"	36
2 74	....	7.43	100.54	..	2.37	VFF.	1,950	2,150	2,350	Br'n	"	"	37
2 74	....	8.84	100.00	.	2.26	V.F.	1,900	2,100	2,300	Gr-p	Not wkd.	"	38
2.47	SO_3 5.19	13 40	101 62	..	2.24	V F	1,700	1,900	2,100	Red.	"	"	39
3.58	....	8 88	98.43	..	2.26	C.	1,800	2,000	2,200	"	"	"	40
2.37	....	5.38	98.35	3	2.37	F.	2,100	2,300	2,500	Gray	Sewerp ..	"	41
1.18	....	4.95	95.56	..	1.90	F.	1,900	2,100	2,300	Br'n	"	"	42
2.37	....	7.66	99.31	3	2.32	V.F.	1,800	2,000	2,200	L-rd	Paving br.	"	43
3.43	....	12 09	99 89	3	2 07	.....	1,700	1,850	2,000	D-rd	Sewer-p	"	44
2.32	....	6.09	101.66	3	2.36	F.	2,100	2,300	2,500	Gray	Not wkd.	"	45
3.32	....	11.49	19.47	3	2.22	V.F.	1,800	2,000	2,200	Red.	"	"	46
2.34	....	8.24	101.42	3	1.69	F.	1,800	2,000	2,150	"	"	"	47
2 03	....	10.15	99.89	3	1 85	F.	1,850	2,050	....	"	"	"	48
3.39	....	9.56	99.34	.	2.33	V.F.	1,700	1,900	2,100	"	Stonew ..	"	49
3.02	... .	9.95	100.32	..	....	V F.	1,700	1,800	2,000	"	Not wkd.	"	50
2.80	....	11 43	99.57	3	1.93	V.F.	1,700	1,900	2,100	"	"	"	51
0.60	....	3.24	100.02	..	......	V. F.	2,250	2,500	2,700	Wh.	Not Wkd.	" ...	53
0.68	....	2.18	100.36	5	1 76	V.F.	2,000	2,250	2,250	Gr'y	"	" ...	54
N. D.	....	2 31	99.71	..	......	.....	.....	.....	.....	.....	"	Robertson.	55
3 80	....	15.34	99.87	4	2.37	V.F.	1,500	1,700	1,900	Red.	Paving B.	Rissmann .	57
3.02	....	14.80	100.16	5	2.41	F.	1,600	1,750	1,900	"	Press B ..	" ...	58
3.25	....	9.91	100.30	4	2.17	F.	2,000	2,200	2,300	"	Red Brick	" ...	59
3.26	.78	10 22	99.78	..	....	F.	.....	......	.....	"	"	Riggs	60

CHEMICAL ANALYSES OF MISSOURI

Running No.		Moisture, HO_2	Combined water, H_2O	Silica, SiO_2	Alumina, Al_2O_3	Total non-detrimentals	Ferric oxide, Fe_2O_3	Lime, CaO	Magnesia, MgO
	JASPER COUNTY—								
61	Potters' clay, Chancy shaft, Joplin	.....	8 48	60.98	21.83	91.29	1.93	0.42	1.95
62	Shale, Briggs' shaft, Joplin	.....	9 84	55.84	22.78	88.46	5.24	0.78	1.26
63	Tallow clay, Rex M. Co. land, Joplin	8.30	9.20	35.50	5.42	.....	9.50	2.23	Tr.
64	Empire Zinc Co., Joplin	.....	18.05	42.40	30.48	.....	6.63	1.70	Tr.
	JEFFERSON COUNTY—								
65	Ball clay, Mammoth mine, DeSoto	.....	12.33	49.04	34 85	96.22	0.71	1.33	1.04
66	Ball clay, Mandels pit, Regina.	.....	12.36	45.97	36.35	94.68	1.08	1.14	1.09
	JOHNSON COUNTY—								
67	Shale, Boyd's pit, Knobnoster	.....	5.84	69.65	20.41	95.40	2.11	1.21	Tr.
68	Shale, Clear Fork	.....	6.60	60.82	23.98	91.40	4.37	0.46	0.45
	LAFAYETTE COUNTY—								
69	Potters' clay, Strasburg mine, Mayview	.....	14.98	48.12	17.04	80.14	3.82	9.90	2.65
70	Shale, Lexington.	.....	7.54	54.03	22.50	84.07	7.90	0.85	2.70
	LAWRENCE COUNTY—								
71	Halloysite, Amora.	.....	18.48	44.12	37.02	99.62	0.33	0.19	0
72	Halloysite, Porter & Coats shaft, Aurora	9.97	7.19	34.53	6.41	.....	2.59	2.20	.....
73	Halloysite, Louisville shaft, Aurora	11.65	6 94	32 44	5.53	.. ..	2.17	2.58	.....
	MARION COUNTY—								
76	Brick clay, Hannibal	.....	5.26	73.60	13.19	92.25	8.48	0.86	0.68
77	Shale, Hannibal	.....	6.16	75.70	9.61	91 47	1.79	2.54	2.11
	MONROE COUNTY—								
81	Fire clay, Williamson, Clapper	0.79	7.12	70.30	20 37	98.56	0.15	0.67	0.33
82	Fire clay, Williamson, Clapper	0.43	7.80	67.76	21.96	97.95	0.69	0 96	0.24
	MONTGOMERY COUNTY—								
83	Flint clay, High Hill	.....	13 34	45 12	40.46	98.92	0.47	0.29	Tr.
	MORGAN COUNTY—								
84	Potters' clay, Priceland, Versailles	.....	11.64	54 10	24.00	89.74	4.01	1.31	1.25
85	Fire clay, Versailles	.....	7.08	68.94	21.18	97.20	0.78	0.61	0.48
	NEWTON COUNTY—								
86	Zinc clay, Butler shaft, Granby	5 03	8.28	34.56	15 61	.....	3 03	4.99	Tr.
87	Zinc clay, Butler shaft, Granby	4.87	6 61	38.25	3.67	.....	8 36	1.22	Tr.
88	Zinc clay, Woodcock & Turner, Granby.	10.90	7 15	42.16	7.70	....	2 64	1.40	Tr.
89	Zinc clay, Woodcock & Turner, Granby	9.35	9.57	32 48	7.35	....	1.07	2.22	Tr.
	OREGON COUNTY—								
93	Kaolin, washed, Arnold land, Thayer	.....	4 52	81.18	12.14	97.84	1.88	0.16	0.14

CLAYS AND SHALES—Continued.

Alkalies ...... $\begin{cases}K_2O\\Na_2O\end{cases}$	Miscellaneous......	Total detrimentals	Grand total.	No. samples tested.	Specific gravity...	Size of grains......	Vitrification—(degrees Fahrenheit). Incipient...	Complete...	Viscous...	Color of burned ware........	Purpose used......	Analyst.........	Running No........
4.69	....	8.99	100.28	4	2.29	C.	1,600	1,850	2100	Buff	Not wkd.	Rissman...	61
4.10	....	11.33	99.79	4	2.27	C.	1,500 1,700	1,700 1,800	1950	Red.	''	....	62
......	ZnO 80.93	......	92.61	..	......	......	......	......	......	......	''	Robertson.	63
......	ZnO 2 86	......	101. 0	..	......	......	......	......	......	......	''	'' ...	64
0.85	....	3.39	100.15	4	1.69	......	1,800	2,100	2,400	Wh.	White w .	Rissman...	65
1.84	....	5.15	99.83	4	1.90	F.	1,800	2,100	2,400	''	''	'' ...	66
8.52	....	4.84	100.24	.	......	C.	2,000	2,150	2,800	Buff	Paving B.	'' ...	67
8.16	....	8 62	99.84	..	......	F C.	1,700	1,850	2,050	Red.	Not Wkd.	'' ...	68
2.97	SO_3-0.27	19.34	99.75	4	2.34	F.C.	1,700	1,850	2,000	Br'n	....	'' ...	69
4.12	....	15.57	99.64	3	2.33	F.	1,600	1,750	1,900	Red.	... .	'' ...	70
0.24	....	0.76	100.38	3	1.91	......	2,200	2,500	2,700	......	Not wkd.	'' ...	71
......	ZnO 37.23	......	99.52	..	......	......	......	......	......	......	''	Robertson.	72
......	ZnO 88.90	......	101.01	..	......	......	......	......	......	......	''	'' ...	73
2.94	....	7.91	100.16	3	2.17	F.	2,000	2,200	......	Red.	Not wkd.	Rissman ...	76
2,65	....	9.09	100.56	3	2.43	C.	2,000	2,200	......	Br'n	''	'' ...	77
0 49	....	1.64	100.20	3	2.48	C.	2,100	2,400	.....	Wh .	Stone W..	'' ...	81
0.24	....	2 13	100 08	3	2.45	C.	2,500	2,600	......	''	'' ..	'' ...	82
0 30	....	1.06	99.98	5	2.33	V.F.	2,235	2,550	2,700	''	Fire brick	'' ...	83
4.01	....	10.58	100.32	5	2.25	V.F.	1,600	1,750	1,900	Br'n	Not wkd.	'' ...	84
0.66	....	2.48	99.68	3	2.33	. . ..	2,200	2,400	2,700	Wh .	''	'' ...	85
......	ZnO 28.40	......	99.00	..	......	......	......	......	......	......	''	Robertson .	86
......	ZnO 21.87	......	99.85	..	....	......	......	......	......	....	''	''	87
......	ZnO 27.80	......	99.75	..	....	....	....	......	......	......	''	''	88
......	ZnO 37.92	.....	99.96	..	......	......	......	...	......	.....	''	''	89
0.18	... .	2.36	100.20	..	......	F.	2,300	2,600	2,700	Gr'y	''	Rissman ...	93

CHEMICAL ANALYSES OF MISSOURI

Running No.		Moisture, HO_2	Combined water, H_2O	Silica, SiO_2	Alumina, Al_2O_3	Total non-detrimentals	Ferric oxide, Fe_2O_3	Lime, CaO	Magnesia, MgO
	OSAGE COUNTY—								
94	Flint clay, Garstang's, Linn	0.37	13 18	47.87	37.14	98.53	0.83	0.42	0.58
	PHELPS COUNTY—								
95	Flint clay, Buskett bank, St. James	.....	14.33	51.05	34.28	99.64	0 39	Tr.	Tr.
96	Flint clay, Buskett bank, St. James	......	13.40	46 33	40.07	99.90	0.50	1.26	0.24
97	Flint clay, Buskett bank, St. James	......	13.60	47.306	38.173	99.08	0.823	0.056	0.09
98	Flint clay, Buskett bank, Rolla	......	9.78	61.408	25.551	96.74	0.281	1.32	1 43
99	Flint clay, Buskett bank, Rolla	3.27	8.00	63.39	22.75	97.41	0.92	0.22	0.05
	PIKE COUNTY—								
100	Shale, Minors land, Bowling Green	1.42	6.42	66.57	15 32	89.73	3 92	3.20	1.08
101	Shale, Louisiana	0 43	7.20	57.01	21.48	88 87	5.77	1.40	0.49
	POLK COUNTY—								
102	Shale, Aldrich	......	18.02	46.26	10 76	75.04	2.65	11.08	7.84
103	Shale, Humansville	......	8.16	56 82	24.48	89 46	3.87	0.83	1.81
	RANDOLPH COUNTY—								
104	Gumbo, Davy C. B. Co , Clifton	2.06	7.82	62.80	17.22	89.90	5.21	0.98	0.78
105	Potters' clay, Hammets farm, Huntsville	1 34	6.00	66.03	21.74	95.11	2.13	0.50	1.01
106	Shale, Stuarts mine, Huntsville	2.45	6.96	56.86	17.97	85.76	9 35	1.67	1.12
107	Shale, 1½ miles N.W., Huntsville	1.41	5.74	58.42	25 36	89 41	6.61	Tr.	Tr.
108	Shale, Moberly B. T. & E. Co., Moberly	1.03	5 51	65 01	19.30	90.85	4.91	1.40	0.40
109	Potters' clay, Lanigan shaft, Moberly	....	7.80	66.26	20.32	94.38	2.80	0.63	0.48
	ST. CHARLES COUNTY—								
110	Gumbo, St. Peters	3.11	9.02	61.19	15.48	88 80	5.49	1.95	1 56
	STE. GENEVIEVE COUNTY—								
111	Shale, Sexaner farm, Ste. Genevieve	1 25	5.71	59 97	21.15	88.04	5.20	1.55	1.10
	ST. LOUIS COUNTY AND CITY—								
112	Fire clay, Christy, St. Louis	2.94	9.25	61.73	23.56	94.54	5.16	0 55	0.15
113	Fire clay, washed, Christy, St. Louis	2 63	8.94	64.35	21.16	94 45	2.63	0.61	0.30
114	Fire clay, Jamieson's, Bartold	1.75	11.61	53.90	28.85	94.36	4.19	1.01	0.11
115	Fire clay, washed, Jamieson's, Bartold	2.26	11.13	55.61	27.36	94.10	2.78	0 87	0.07
116	Fire clay, Coffin & Co., Gratiot	......	11.44	56 47	28.24	96 15	2 26	1.00	0.32
117	Fire clay, Coffin & Co., Gratiot.	1.27	8.42	48.27	31.35	93.40	4 97	2.13	0.21
118	Fire clay, washed, Coffin & Co., Gratiot	......	11.61	55.00	29.62	96.23	2.18	0.91	0.29
119	Fire clay, washed, Coffin & Co., Gratiot	0.74	8 77	56.01	31.68	87.40	1.18	1.17	0.21
120	Fire clay, Sattler, Columbia B. road	4 06	11.86	51 66	30.78	94.30	2 90	1.22	0.68

CLAYS AND SHALES—Continued.

Alkalies ... $\left\{ \begin{matrix} K_2O \\ N_2O \end{matrix} \right.$	Miscellaneous.	Total detrimentals.	Grand total........	No samples tested.	Specific gravity....	Size of grains.	Vitrification—(degrees Fahrenheit). Incipient..	Complete..	Viscous...	Color of burned ware	Purpose used.	Analyst	Running No ....
0 50	....	2.33	100 86	3	2.38	F.	2,250	2,450	2,600	Gr'y	Not wkd.	Rissman..	94
0.11	....	0.50	100.15	..	.....	......	......	......	......	W.	Fire brick	C.E. Wait.	95
.....	....	2.00	101 80	..	......	......	....	.....	.... .	"	"	Cleveland .	96
1.41	....	2.381	101.47	..	......	......	......	......	......	"	"	Seaman....	97
......	....	8.033	99.873	..	......	......	......	......	......	"	"	"	98
0.89	.. ..	1.983	99 848	..	......	......	......	......	......	"	"	"	99
2.94	....	10.99	100.72	3	2.41	C.	1,850	2,000	2,150	Br'n.	Not wkd.	Robertson.	100
3.81	....	11 47	100.34	3	2.89	C.	1,600	1,700	1,900	Red.	"	"	101
3.17	....	24.74	99.78	4	2.56	C.	2,175	2,200	2,225	Buff.	Not wkd.	Rissmann .	102
3.80	....	10 26	99.72	4	2.53	F.C.	1,700	1,900	2,100	Red.	"	"	103
3.63	....	10.60	100.70	8	1.98	V.F.	1,600	1,750	1,900	Red.	R. R. Bal.	Robertson.	104
1.61	....	5.28	100.39	3	2.53	C.	2,000	2,200	2,400	Buff.	Not wkd	"	105
2.61	....	14.75	100.51	4	2.34	F. C.	1,800	1,950	2,100	Red.	"	"	106
2.97	....	9.58	98 99	3	2.15	F.	1,700	1,850	1,950	"	"	"	107
2.60	....	9.31	100.16	3	2.41	C.	1,850	2,050	2,250	"	Paving b.	"	108
2.04	....	5.45	99.83	5	2.52	C.	2,000	2,200	2,400	Buff.	Not wkd.	Rissmann..	109
2.82	....	11 82	100.62	8	2.05	F.	1,650	1,800	1,950	Red.	R. R. Bal.	Robertson .	110
8.88	....	11 77	99.81	4	2.41	C.	1,600	1,750	1,950	Red.	Not wkd.	Rissmann .	111
1.00	TiO_2 0.96 SO_3 0.56 S 0 12	7.30	101.84	5	2.47	C.	2,100	2,300	2,500	Dark	Fire brick	Woodward	112
0.51	TiO_2 1.07 SO_3 0.35 S 0.09	4.81	99 26	4	2 13	C.	2,200	2,400	2,700	Buff	Glass pots	"	113
0.85	TiO_2 1.05 SO_3 0.22 S 0.34	6.86	101.22	4	2.40	C.	2,200	2,400	2,600	Dark	Fire brick	"	114
0.71	TiO_2 1.36 SO_3 0.51 S 0 23	5.25	99 35	3	1.92	C.	2,200	2,400	2,700	Buff	Glass pots	"	115
0.45	....	4.03	100.18	3	2.42	C.	2,200	2,400	2,600	Dark	Fire brick	"	116
1.28	Organ 2.10	8.59	100.00	3	......	C.	.....	......	....	"	"	Elsom......	117
0.27	....	8.65	99.88	3	2.11	C.	2,200	2,400	2,600	Buff	Glass pots	Woodward	118
0.09	Organ 0.20	2.60	100 00	..	.....	C.	.....	......	.....	"	"	Elsom.....	119
0.99	TiO_2 1.85	6 28	100.58	3	2.40	F.	2,100	2,300	2,500	Dark	Not wk'd	Woodward	120

CHEMICAL ANALYSES OF MISSOURI

Running No.		Moisture, H_2O	Combined water, H_2O	Silica, SiO_2	Alumina, Al_2O_3	Total non-petrimentals	Ferric oxide, Fe_2O_3	Lime, CaO	Magnesia, MgO
	ST. LOUIS COUNTY AND CITY—*Con.*								
121	Fire clay, Sattler, Columbia B. road	......	13.26	53.54	28.21	95 01	4.00	1.01	0.11
122	Fire clay, washed, Sattler, Columbia B. road	......	.....	.....	.....	.....	3.29	0.47	0.06
123	Fire clay, washed, Sattler, Columbia B. road	3.68	11.42	52 98	28.87	93.17	2.48	0 51	0.87
124	Fire clay, Parker & Russell, St. Louis	2.72	7.73	67.47	19.33	94.53	2 56	0.41	0.07
125	Fire clay, Evens & Howard, St. Louis	2.74	10 20	59.36	23.26	92.82	3.06	0.65	0.42
126	Fire clay, Laclede mine, St. Louis	2.86	11.55	57.34	24.68	93.57	2.60	0.90	0.49
127	Pipe clay, Laclede mine, St. Louis	......	7.70	59.96	15.76	83 42	7.72	0 60	0.93
128	Shale, Laclede mine, St. Louis	....	6.67	54.57	23.61	84 85	7.88	0.52	1.48
129	Shale, Prospect Hill, St. Louis	.....	7.77	60 70	18.22	85.69	7.58	2.68	Tr.
130	Shale, Barretts	1 16	13 37	49.69	17.40	81 62	4.01	8.07	4.16
131	Brick clay, Hydraulic Press B. Co., St. Louis	2.18	3.08	73 92	11 65	90.83	4.74	1.45	0.60
132	"Alluvium," Missouri River settings	5.14	8.75	51.68	23.65	89.22	6.68	1.40	0.20
133	Potters' clay, Rennebergs, Allenton	......	6.48	60.07	22.81	89.36	2.71	1.65	1.55
	SALINE COUNTY—								
134	Potters' clay, Oer pit, Slater	1.69	8.25	50 86	32.34	92 64	3.90	1.04	0.37
	SCHUYLER COUNTY—								
135	Potters' clay, Chariton river, Glenwood	......	12.78	53.54	15.39	81.71	4.17	8.54	2.17
	SCOTT COUNTY—								
136	Potters' clay, Anderson place, Commerce	.....	8 18	71.78	17.01	96.92	2.01	0.34	0.43
	SHANNON COUNTY—								
138	Kaolin, Trusty land, Winona	1.20	6.20	56.74	27.29	91.43	6.87	0.26	0.18
	SHELBY COUNTY—								
139	Fire clay, Higgins pit, Lakenan	0.40	6.74	58.50	30.50	95.15	2.34	1.20	0.51
140	Fire clay, Higgins pit, Lakenan	1.42	10.03	67.60	18.97	91.92	1.25	0.20	Tr.
	STODDARD COUNTY—								
141	Potters' clay, Dexter	......	7 62	68.50	20 81	96.93	1.79	0.77	Tr.
	VERNON COUNTY—								
143	Shale, Deerfield	.....	8 69	58.90	21.38	88.97	7.09	0.57	1.66
144	Shale, Prewits' bank	......	7.71	54.54	23.26	85 51	7.34	1.44	1 82
145	Osage river	.....	8.39	55.20	22.89	85.97	6 56	2.64	1.37

CLAYS AND SHALES—Continued.

Alkalies (K_2O, Na_2O)	Miscellaneous	Total detrimentals	Grand total	No. samples tested	Specific gravity	Size of grains	Vitrification—(degrees Fahrenheit). Incipient	Complete	Viscous	Color of burned ware	Purpose used	Analyst	Running No.
0.76	... ...	4.68	99.69	...	...	F.	...	...	...	Dark	... ...	Hunichk...	121
0.66	...	3.49	...	...	...	F.	...	...	...	Buff	Glass pots	"	122
1.01	... ...	5 12	98 29	...	...	F.	2,200	2,400	2,700	"	"	Woodward	123
1.07	TiO_2 Tr.; SO_3 0.24; S 0.66	5.14	99.67	4.	2.44	V.C.	2,250	2,450	2,700	"	F.B. ret's	"	124
0.63	TiO_2 1.01; SO_3 0.35; S 0.39	5.67	98.49	3	2 41	C.	2,250	2,450	2,650	"	Fire brick	"	125
0.67	TiO_2 1.60; SO_3 0.54; S 0.98	6.30	99.87	3	2.45	C.	2,250	2,450	2,650	"	"	"	126
3.66	SO_3 0.73; S 0.29	13 92	97.34	3	2.05	F.	1,800	1,950	2,150	Red	Sewerpi'e	"	127
3.55	SO_3 0.44; S 0.03	13.90	98.75	4	2.32	C.	1,800	2,000	2,300	"	"	"	128
3.67	...	13 93	99.62	2	2.42	C.	1,700	1,900	2,100	"	Roof tile.	Chauvenet	129
2.73	...	18.97	100.59	...	...	V.C.	1,925	1,950	2,000	Gray	Not wd'k	Rissman...	130
3.13	... ...	9 90	100.73	3	1.98	C.	1,800	1,950	2,050	Red	Red brick	Robertson.	131
2.23	...	10.46	99.68	...	...	V V F	...	...	...	"	...	Rissman...	132
4.42	...	10.33	94 69	4	2 23	C.	1,700	1,900	2,100	Buff	Not wk'd	"	133
2.01	... ...	7.32	99 96	3	2.48	C.	1,900	2,100	2,300	...	...	Rissman...	134
3.20	... ...	18 08	99.77	3	2 13	F.	1,700	1,850	2,000	Red.	Not wkd.	Rissman...	135
0.78	...	3.56	100.48	3	2.03	F.	1,950	2,150	2,350	Buff.	Stonew...	" ...	136
1.21	...	8.52	99.95	3	1.66	V.F.	1,800	2,000	2,200	...	Not wkd.	" ...	138
0.30	... ...	4.35	100.50	3	2 41	C.	2,200	2,400	2,600	Buff.	Stonew...	" ...	139
0.96	... ...	2.41	100.33	3	2.38	F.	2,000	2,200	2,600	Buff.	"	" ...	140
0 53	...	3.09	100.02	4	2.13	F.	2,000	2,250	2,600	Buff.	Stonew...	" ...	141
1.52	...	10.84	99 81	5.	2.43	F.C.	1,800	2,000	2,150	Red.	Not wkd..	" ...	143
4.12	...	14.72	100.23	5	2.40	F	1,500	1,700	1,900	"	"	" ...	144
3.54	SO_3 Tr.	14 11	100.08	4	2.41	F.	1,600	1,800	2,000	"	"	" ...	145

CHEMICAL ANALYSES OF MISSOURI

Running No.		Moisture, H_2O	Combined water, H_2O	Silica, SiO_2	Alumina, Al_2O_3	Total non-detrimentals	Ferric oxide, Fe_2O_3	Lime, CaO	Magnesia, MgO
	ST. LOUIS COUNTY AND CITY—*Con.*								
121	Fire clay, Sattler, Columbia B. road	......	18.26	58.54	28.21	95 01	4.00	1.01	0.11
122	Fire clay, washed, Sattler, Columbia B. road	.....	.....	.....	....	....	3.29	0.47	0.06
123	Fire clay, washed, Sattler, Columbia B. road	3.66	11.42	52 98	28 87	93.17	2.48	0 51	0 87
124	Fire clay, Parker & Russell, St. Louis	2.72	7.73	67.47	19.33	94.53	2 56	0.41	0.07
125	Fire clay, Evens & Howard, St. Louis	2.74	10 20	59.36	23.26	92.82	3.06	0 65	0.42
126	Fire clay, Laclede mine, St. Louis	2.86	11.56	57.84	24.68	93.57	2.60	0 90	0 4[illegible]
127	Pipe clay, Laclede mine, St. Louis	.....	7.70	59.96	15.76	83 42	7.72	0 60	[illegible]
128	Shale, Laclede mine, St. Louis	....	6.67	54.57	23.61	84 85	7.88	0 52	1 [illegible]
129	Shale, Prospect Hill, St. Louis	.....	7.77	60 70	18.22	85.69	7.58	2.[illegible]	Tr
130	Shale, Barretts	1 16	18 87	49.69	17.40	81 62	4.01	8 07	4
131	Brick clay, Hydraulic Press B Co., St. Louis	2.18	8.08	78 92	11 65	90.83	4.74	1 45	[illegible]
132	"Alluvium," Missouri River settings	5.14	8.75	51.68	28.65	89.22	6.63	1 4[illegible]	
133	Potters' clay, Renneberge, Allenton	......	6.48	60.07	22.81	89.36	2.71	1.[illegible]	
	SALINE COUNTY—								
134	Potters' clay, Oer pit, Slater	1.69	8.25	50 86	32.34	92 64	3.90	1.[illegible]	
	SCHUYLER COUNTY—								
135	Potters' clay, Chariton river, Glenwood	......	12.78	58.54	15.39	81.71	4.17	[illegible]	
	SCOTT COUNTY—								
136	Potters' clay, Anderson place, Commerce	....	8 18	71.78	17.01	96.92	2.01	[illegible]	
	SHANNON COUNTY—								
138	Kaolin, Trusty land, Winona	1.20	6.20	56.74	27.29	91 43	6 87	[illegible]	
	SHELBY COUNTY—								
139	Fire clay, Higgins pit, Lakenan	0.40	6 74	58.50	30.50	95.15	2.[illegible]		
140	Fire clay, Higgins pit, Lakenan	1.42	10.03	67 60	18.97	91.92	1 [illegible]		
	STODDARD COUNTY—								
141	Potters' clay, Dexter	....	7 62	68 50	20 81	96.93	1[illegible]		
	VERNON COUNTY—								
143	Shale, Deerfield	.....	8 69	58.90	21.38	88 97	[illegible]		
144	Shale, Prewitts' bank	....	7 71	54.54	23.26	85 51			
145	Osage river	..	8.38	55.20	22 39	85.97			

CLAYS AND SHALES--Continued.

Alkalies ..... K_2O Na_2O	Miscellaneous.......	Total detrimentals.	Grand total.......	No. samples tested.	Specific gravity.....	Size of grains.......	Vitrification—(degrees Fahrenheit). Incipient..	Complete..	Viscous....	Color of burned ware........	Purpose used.....	Analyst	Running No........
0.76	....	4.68	99.69	..	......	F.	......	......	......	Dark	....	Hunichk...	121
0.66	....	8.49	......	..	.....	F.	.....	....	......	Buff	Glass pots	"	122
1.01	....	5 12	98 29	..	......	F.	2,200	2,400	2,700	"	"	Woodward	123
1.07	TiO_2 Tr. SO_3 0.24 S 0.66	5.14	99.67	4	2.44	V.C.	2,250	2,450	2,700	"	F.B. ret's	"	124
0.63	TiO_2 1.01 SO_3 0.35 S 0.39	5.67	98.49	3	2.41	C.	3,250	2,450	2,650	"	Fire brick	"	125
0.67	TiO_2 1.60 SO_3 0.54 S 0.98	6.30	99.87	3	2.45	C.	2,250	2,450	2,650	"	"	"	126
3.66	SO_3 0.73 S 0.29	13 92	97.34	3	2.05	F.	1,800	1,950	2,150	Red	Sewerpi'e	"	127
3.55	SO_3 0.44 S 0.03	13.90	98.75	4	2.32	C.	1,800	2,000	2,300	"	"	"	128
3.67	....	13 93	99.62	2	2.42	C.	1,700	1,900	2,100	"	Roof tile.	Chauvenet	129
2.73	....	18.97	100.59	..	....	V.C.	1,925	1,960	2,000	Gray	Not wd'k	Rissman...	130
3.13	....	9 90	100.73	3	1.98	C.	1,800	1,950	2,050	Red	Red brick	Robertson.	131
2.28	....	10.46	99.68	..	....	V V F	......	......	......	"	....	Rissman...	132
4.42	....	10.83	94 69	4	2 23	C.	1,700	1,900	2,100	Buff	Not wk'd	"	133
2.01	....	7.32	99.96	3	2.48	C.	1,900	2,100	2,300	......	....	Rissman...	134
3.20	....	18 08	99.77	3	2 13	F.	1,700	1,850	2,000	Red.	Not wkd.	Rissman ...	135
0.78	....	3.56	100.48	3	2.03	F.	1,950	2,150	2,350	Buff.	Stonew...	" ...	136
1.21	....	8 52	99.95	3	1.66	V.F.	1,800	2,000	2,200	......	Not wkd.	" ...	138
0.30	....	4.85	100.50	3	2 41	C.	2,200	2,400	2,600	Buff.	Stonew...	" ...	139
0.96	....	2.41	100.33	3	2.38	F.	2,000	2,200	2,600	Buff.	"	" ...	140
0 53	....	3.09	100.02	4	2,13	F.	2,000	2,250	2,600	Buff.	Stonew...	" ...	141
1.52	....	10.84	99 81	5	2.43	F.C.	1,800	2,000	2,150	Red.	Not wkd..	" ...	143
4.12	....	14.72	100.23	5	2.40	F.	1,500	1,700	1,900	"	"	" ...	144
3.54	SO_3 Tr.	14.11	100.08	4	2.41	F.	1,600	1,800	2,000	"	"	" ...	145

PHYSICAL TESTS OF THE MISSOURI CLAYS.

The following tests of the physical properties of the Missouri clays and shales have been executed in carrying on the study of the samples collected for the report, which are herewith brought together and arranged for convenience of study and reference. They have all been previously recorded in the detailed consideration of the individual deposits.

For the methods of making the physical tests, and the proper interpretation of the results reference is made to the chapters on the physical properties.

Physical Tests on the Missouri Clays.

LOCALITY	Size of grain	Tensile strength. No. samples tested	Tensile strength. Maximum	Tensile strength. Average	Per cent of water used for paste	Plasticity, by feel	Shrinkage—per cent. No. samples	Shrinkage—per cent. In air drying	Shrinkage—per cent. Speed	Shrinkage—per cent. No. samples	Shrinkage—per cent. In burning	Shrinkage—per cent. Speed	Shrinkage—per cent. Total shrinkage	Vitrified at (degrees F.) Incipient	Vitrified at (degrees F.) Complete	Vitrified at (degrees F.) Viscous	No. samples	Specific gravity	Per cent of impurities
ANDREW COUNTY—																			
Shale, R'y cut, Amazonia	Fine	6	153	137	20.8	Plastic	14	5.8	Rap.	2	7.7	Rap.	13.5	1,700	1,850	2,150	...	...	...
ATCHISON COUNTY—																			
Shale, Milton	F.	7	123	108	22.0	Plastic	14	5 2	R.	1	9.9	?	15 1	1,500	1,700	1,900	...	...	...
Shale, Milton	Coarse	7	136	127	21.6	"	14	5 6	R.	1	5.2	R.	10.5	1,700	1,900	2,050	..	...	...
AUDRAIN COUNTY—																			
Fireclay, Mexico	C.	8	69	62	14.8	Lean	9	4 4	R.	4	6.4	R.	10 8	2,200	2,400	2,600	3	2.46	3.25
Fireclay, Vandalia	V. F.	9	100	89	14.5	Rather lean	13	4.25	R.	1	6 9	Slow	11.15	2,300	2,500	2,700	3	2 43	2.94
Fireclay, washed, Vandalia	V. F.	6	83	71.5	...	Lean	9	3.6	R.	2	6.4	S.	10.0	2,300	2,500	2,700	...	...	2.44
BARTON COUNTY—																			
Potters' clay, Waltimers, 4 Ms. S. of Lamar	F.	5	98	87	19.2	Rather lean	16	5.5	R.	1	6.1	R.	11.60	2,000	2,200	2,400	3	2.46	4 45
Potters' clay, Wear coal shaft, Minden	F.	5	203	187	19.2	Plastic	15	7.6	Med.	2	4.0	M.	11.60	1,700	1,850	2,000	3	2.54	13.33
BATES COUNTY—																			
Shale, Foster	F.	8	159	149	20.0	Plastic	12	6.1	R.	2	5.3	R	11.4	1,600	1,800	2,000	2	2.25	15.33
BOLLINGER COUNTY—																			
Kaolin, Glen Allen	V. F.	6	14	12	23.2	Lean	10	4.0	R.	4	8.4	S.	12.4	2,200	2,500	.....	8	1.89	1.89
BOONE COUNTY—																			
Fireclay, Fay bank, Columbia	C.	5	160	143	15 8	Plastic	20	5.9	R.	9	4.6	S.	10.5	2,050	2,250	2,450	3	2 49	3.66

PHYSICAL TESTS ON THE MISSOURI CLAYS Continued.

LOCALITY.	Size of grain	Tensile strength. No. samples tested	Tensile strength. Maximum	Tensile strength. Average	Per cent of water used for paste	Plasticity, by feel	Shrinkage - per cent. No. samples	Shrinkage - per cent. In drying	Shrinkage - per cent. Speed	Shrinkage - per cent. No. samples	Shrinkage - per cent. In burning	Shrinkage - per cent. Speed	Shrinkage - per cent. Total shrinkage	Vitrified at (degrees F.) Incipient	Vitrified at (degrees F.) Complete	Vitrified at (degrees F.) Viscous	No. samples	Specific gravity	Per cent of impurities
CALDWELL COUNTY																			
Potters' clay, Kingston shaft, Kingston	F	6	265	180	2.47	Very plastic	12	10.8	V. S.	1	4 2	M R.	65 0	1,200	1,750	1,900	....	....	....
CALLAWAY COUNTY																			
Fireclay, Fulton	C	8	40	40	14 8	Lean	14	8 8	R.	4	7.2	M.	11 0	2,800	2,600	2,750	8	2.44	2.55
Fireclay, New Bloomfield	V. F.	7	68	58	17 8	Plastic. ...	14	5 8	R.	7	9 0	V. S	14.8	2,200	2,400	2,600	8	2 27	8.21
Potters' clay, Moore's place, Guthrie	V. F	7	113	81	21.6	"	16	6 9	R.	8	9 1	S.	16.0	1,900	2,100	2,800	4	2.18	4.69
Potters' clay, washed, Moore's pl., Guthrie	V. F	7	101	71	15 6	"	11	6 4	R.	2	8.4	S.	14 8	2,000	2,200	2,400	....	....	8.76
CAPE GIRARDEAU COUNTY																			
Kaolin, Brooks land, Cape Girardeau	F	7	26	24	28 7	Very lean	15	2 4	R	1	6.3	S.	8.7	2,800	2,600	....	8	2 02	1.27
CARROLL COUNTY																			
Gumbo, Davy C. B. Co., Norborne	V. F.	8	410	380	22.3	Very plastic.	12	9 6	V. S.	2	1.4	S.	11 0	1,600	1,750	1,900	8	2.01	18.41
CARTER COUNTY																			
Kaolin, washed, Mo. L. & M. Co., Chilton,	V. F.	6	28	20	18 0	Lean	12	5 8	R	2	10.4	V. S.	16.2	2,800	2,500	......	...	......	1.77
CASS COUNTY																			
Potters' clay, Harrisonville	F. to C.	6	270	240	20 2	Very plastic	17	7.5	M.	2	4 7	M.	12.2	1,700	1,900	2,100	4	2.84	8.88
Potters clay, washed, Harrisonville	F	7	265	231	18 2	"	12	8 0	M	2	4.8	M.	12 8	1,750	1,950	2,150	...	.....	7.91
CHRISTIAN COUNTY																			
Shale, Billings	F	6	180	86	24 1	Plastic.	14	7 3	R	1	5.8	M S.	18.1	2,000	2,200	2,400	4	2.10	6 02

COLE COUNTY—																			
Brick clay, Jefferson City	C.	7	149	131	17.2	Lean	16	5.7	S.	1	4.3	R.	10.0	2,000	2,000	2,300	3	2.09	10.09
COOPER COUNTY—																			
Brick clay, Boonville	F.	10	112	97	19.3	Very lean	16	4.7	M.R.	1	5.1	R.	9.8	2,000	2,000	2,300	3	2.20	10.88
Shale, near Boonville	F. C.	7	243	212	24.5	Very plastic	16	8.1	R.	1	6.6	R.	14.7	1,500	1,700	1,900	5	2.39	15.98
CRAWFORD COUNTY—																			
Flint clay, Leasburg	V. F.	7	10	8	15.1	Extr'ly L.	12	3.1	R.	2	11.6	S.	14.7	2,350	2,700	2,700	3	2.55	2.89
Flint clay, Sankey coal mine	C.	6	50	44	24.2	Rather lean	20	4.9	R.	6	10.4	M.	15.4	2,100	2,300	2,500	3	2.10	5.29
FRANKLIN COUNTY—																			
Flint clay, Dry Branch	V. F.	6	15	14	15.6	Extr'ly L.	14	3.2	R.	2	9.6	S.	12.8	2,350	2,700	2,700	4	2.43	1.64
Ball clay, Union	F.	24	59	49.7	24.2	Plastic	14	5.1	R.	4	14.0	S.	19.1	2,200	2,400	2,650	3	1.98	2.45
GASCONADE COUNTY—																			
Flint clay, Drake	V. F.	8	21	14	17.0	Lean	17	3.3	R.	2	10.2	S.	13.5	2,300	2,500	2,750	3	2.35	1.93
Flint clay, Owensville	F.	7	38	32	15.0	"	17	3.8	R.	1	4.3	R.	8.1	2,050	2,200	2,350	....	.....	6.55
GRUNDY COUNTY—																			
Potters' clay, Trenton	C.	6	227	209	19.2	Very plastic	15	7.2	M.R.	2	1.6	M.R.	8.8	1,750	1,700	2,050	....	.....	......
Shale, Trenton	C.	6	221	198	21.5	Plastic	20	7.2	R.	2	3.1	R.	10.3	1,500	1,700	1,850	....	.....	......
HENRY COUNTY—																			
Potters' clay, Calhoun	V. F.	8	168	150	16.5	Plastic	12	5.5	R.	3	2.2	S.	7.7	2,100	2,300	2,500	4	2.34	5.04
Potters' clay, Dunlap pit, Clinton	V. F.	8	127	112	19.0	"	12	6.1	R.S.	2	5.9	S.	12.0	2,000	2,200	2,400	2	2.23	6.08
Potters' clay, Frowein pit, Clinton	V.F.to F.	4	164	143	21.4	"	13	7.7	R.	3	4.0	R.	11.7	1,950	2,150	2,350	3	2.37	7.43
Potters' clay, Grant farm, Clinton	V. F.	4	207	189	21.4	"	12	7.8	R.	2	4.0	S.	11.8	1,900	2,100	2,300	3	2.26	8.84
Shale, Grant farm, Clinton	V. F.	4	159	144	21.8	"	12	7.3	R.	2	5.7	S.	13.0	1,700	1,900	2,100	2	2.24	13.40
Shale, Town creek, Clinton	C.	4	40	35	16.5	Very lean	12	3.9	R.	3	2.4	R.	6.3	1,800	2,000	2,200	3	2.26	8.88
Potters' clay, Mo. Clay Co., Deepwater	F.	4	83	64	17.0	Lean	10	5.9	R.	2	4.4	R.	10.8	2,100	2,300	2,500	3	2.37	5.38
Fire clay, Mo. Clay Co., Deepwater	F.	4	217	175	15.0	Very plastic	7	7.7	R.	5	2.8	R.	10.0	1,900	2,100	2,300	3	1.90	4.95
Shale, Mo. Clay Co., Deepwater	V. F.	4	140	124	20.4	Plastic	12	5.7	R.	1	4.0	R.	9.7	1,800	2,000	2,200	3	2.32	7.66

PHYSICAL TESTS ON THE MISSOURI CLAYS—Continued.

	Size of grain	Tensile strength.			Per cent of water used for paste	Plasticity, by feel	Shrinkage—per cent.							Vitrified at (degrees F.)			No. Samples	Specific gravity	Per cent of impurities
		No. samples tested	Maximum	Average			No. samples	In air drying	Speed	No. samples	In burning	Speed	Total shrinkage	Incipient	Complete	Viscous			
Pipe clay, Dickey Co., Deepwater	V. F.	8	140	100	21.0	Plastic	11	5 8	R.	2	3.3	R.	9.1	1,700	1,850	2,000	....	2 07	12.09
Potters' clay, Gilkerson ford	F.	4	60	54	18.0	L. to very L.	10	5.3	R.	2	6.0	R	11.3	2,100	2,300	2,500	3	2.36	6.09
Shale, Gilkerson ford	V. F.	4	81	76	18 8	Very lean	11	4.7	R.	3	4.0	R.	8.7	1,900	2,000	2,200	3	2.22	11.19
Brick clay, Gilkerson ford.	F.	6	242	208	17.8	Plastic	8	7.6	R.	2	4.0	R.	11.6	1,800	2,000	2,150	3	1.69	8.24
Brick clay, Hartwell	F.	8	275	239	15.7	"	4	7.7	V. S.	1	2 2	R.	9.9	1,850	2,050	....	3	1 89	10.15
Potters' clay, Field creek	V. F.	8	163	140	18.7	Plastic	11	6.6	R.	1	3.9	R.	10.5	1,800	1,900	2,200	3	2.33	9.56
Shale, Field creek	V F.	5	139	115	20.2	"	12	6.4	R.	3	4.8	S.	11 2	7,650	1,850	2,050	....	....	9.96
Potters' clay, Vickerland	V. F.	8	157	141	28.2	"	11	7.6	R.	1	6.7	S.	14.3	1,700	1,900	2,100	3	1.93	11 43
HOLT COUNTY—																			
Shale, Plummer quarry, Forest City	....	6	214	190	21.5	Rather plas	14	6.4	.....	1	7.9	......	14.3	1,650	1,800	.....	...	.....	.....
HOWELL COUNTY—																			
Kaolin (washed) Macey place, Sterling	V. F.	7	71	59	35 5	Rather lean	11	9.2	R.	4	15 0	S.	24.2	2,250	2,500	....	....	.....	3.24
Kaolin, Gates place, West Plains	V. F.	6	128	113	30.4	Plastic	17	8 5	R.	4	9.5	S.	18.0	2,000	2,250	2,500	5	1 76	2.18
JACKSON COUNTY—																			
Potters' clay, K. C., C & C. Co., K. C	C	6	179	162	20.0	Plastic	9	7.7	S.	1	1.2	S.	8.9	1,550	1,750	1,900	3	2 88	......
Shale, D. B. & T. Co., Kansas City	V. F.	6	128	115	21.5	"	12	5.9	R.	3	2.8	R. S.	8.7	1,500	1,700	1,900	4	2.87	15.84
Shale, North Bluff, Kansss City	F.	12	226	198	22.3	Very plastic	12	6.9	R.	1	4.8	R.	11.7	1,600	1,750	1,900	5	2.41	14.80
Brick clay, Kansas City	F.	5	175	151	18.4	Lean	14	5 1	S.	1	5.7	R.	10.8	2,000	2,200	2,200	4	2.17	9 91

JASPER COUNTY—																			
Potters' clay, Chaney shaft, Joplin	C.	6	239	209	15.8	Very plastic	16	7.7	S.	B.	6.2	S.	13.2	1,650	1,850	2,100	4	2.29	8.99
Shale, Briggs' shaft, Joplin	C.	5	148	141	20.0	Plastic	14	7.7	R.	2	3 4	R.	9.4	1,700	1,800	1,950	4	2.27	11 3
JEFFERSON COUNTY—																			
Ball clay, Mammoth mine, DeSoto	V. F.	6	228	198	23 4	Plastic	14	7.7	R.	5	9.8	S.	17.5	1,800	2,100	2,400	4	1 69	3.93
Ball clay, Regina	V. F.	6	108	99	22.7	"	18	7.7	R.	1	12.2	S.	19.9	7,800	2,100	2,400	4	1.90	5.15
JOHNSON COUNTY—																			
Shale, Boyd pit, Knobnoster	C.	5	129	109	19.1	Plastic	14	5.8	R.	1	5.2	R.	11.0	2,000	2,150	2,300	....	.....	4.84
Shale, Clear Fork	F. C.	6	103	60	20 3	"	12	5.4	R.	4	4.3	R.	9.7	1,700	1,850	2,050	....	.....	8 62
LAFAYETTE COUNTY—																			
Fire clay, Strasking mine, Mayview	F. to C.	5	284	267	22 3	Very plastic	15	8 8	V.S.	3	0.8	R.	9.6	1,700	1,850	2,000	4	2.34	19.34
Shale, Lexington	F.	5	155	138	23.1	Plastic	16	6.6	R.	1	7.4	R.	14.0	1,600	1,750	1,900	3	2.83	15.57
LAWRENCE COUNTY—																			
Halloysite, Aurora	....	6	42	38	30 0	Very lean	7	5.2	......	4	15.8	......	21.0	2,200	2,500	......	3	1 91	0.76
LINN COUNTY—																			
Shale, Bottomly shaft, Brookfield	F.	6	113	102	20.0	Plastic	14	6.2	R.	1	7.0	R.	13.2	1,600	1,750	......	....	.....	......
MACON COUNTY—																			
Shale, Macon City	C.	7	70	57	19.2	Rather lean	11	4.5	R.	2	5.5	R.	10.0	1,850	2,000	2,150	....	.....	......
MARION COUNTY—																			
Brick clay, Hannibal	F.	7	148	126	18.4	Lean	14	4.5	M.	1	5.9	M.	10.4	2,000	2,200	......	3	2.17	7.91
Shale, Hannibal	....	6	125	105	18.4	"	15	4.4	R.	1	5.9	S.	10.3	2,000	2,200	.....	3	2.43	9.09
Shale, Hannibal	C.	7	161	135	20.8	Plastic	18	7.0	R.	1	4.7	R.	11 7	1,750	1,950	2,100	....	.....	......
MERCER COUNTY—																			
Shale, Princeton	C.	4	292	258	21.5	Very plastic	12	8 5	S.	1	2.5	S.	11.0	1,800	2,000	2,200	....	....	......
Shale, Princeton	C.	7	130	93	20.5	"	14	5 6	R.	1	6.5	R.	12.1	1,700	1,850	......	....	.....	.....

PHYSICAL TESTS ON THE MISSOURI CLAYS—Continued.

	Size of grain	Tensile strength			Per cent of water used for paste	Plasticity, by feel	Shrinkage—per cent.							Vitrified at (degrees F.)			No. samples	Specific gravity	Per cent of impurities
		No. samples tested	Maximum	Average			No. samples	In air drying	Speed	No. samples	In burning	Speed	Total shrinkage	Incipient	Complete	Viscous			
MONROE COUNTY—																			
Fire clay, Williamson's, Clapper	C.	7	109	92	15.3	Plastic	16	5 0	R.	3	5.2	R.	10.2	2,100	2,400	2,700	3	2.43	16.4
Fire clay, Williamson's, Clapper	C.	7	39	33	14.0	Lean	16	8 8	R.	5	1.5	R.	5.3	2,500	2,600	2,700	3	2.45	2.13
MONTGOMERY COUNTY—																			
Flint clay, High Hill	V.F.	8	18	14	17.2	Extremely 1	15	3.4	R.	4	9.9	S.	13.3	2,350	2,550	2,700	5	2.33	1.06
MORGAN COUNTY—																			
Potters' clay, Price land, Versailles	F.	7	175	150	24 2	Very plastic	15	10.4	V.S.	1	5 4	R.	15.80	1,600	1,750	1,900	5	2.25	10.58
Fire clay, Versailles	....	7	98	90	15.8	Plastic	16	3.3	R.	4	4 0	S.	9.3	2,200	2,400	2,700	3	2.33	2.48
NODAWAY COUNTY—																			
Shale, Burlington Junction	F.	5	237	211	21.8	Plastic	13	7.0	S.	2	1.4	......	8 4	1,450	1,600	1,750	....	......	.....
Shale, Burlington Junction	C.	5	222	209	22 5	"	15	8 1	M.	1	6 3	R.	14.4	1,600	1,830	2,000	....	......	.....
Shale, Bird shaft, Quitman	C.	6	265	234	23.0	"	14	7.8	R.	2	3.6	R.	11.4	1,700	1,950	1,950	....	......	.....
OREGON COUNTY—																			
Kaolin, washed, Arnold land, Thayer	F.	5	14	13	23.0	Lean	13	3.2	R.	1	3.3	V.S	6.5	2,300	2,600	2,700	....	......	2.36
OSAGE COUNTY—																			
Flint clay, Garstang, Linn	F.	6	25	24	16.7	Very lean	20	3 5	R.	4	10.3	S.	13 8	2,250	2,450	2,600	3	2.38	2.33

PIKE COUNTY—																		
Shale, Minor land, Bowling Green	C.	7	144	128	1.75	Slightly lean	17	6.4	M.	2	5.4	M.	11.8	1,850	2,000	2,150	3	2.41	10.99
Shale, Louisiana	C.	6	114	98	20 8	Rather lean	17	7 3	R.	1	5.0	R.	12.3	1,600	1,700	1,900	3	2.39	11.47
POLK COUNTY—																		
Shale, Aldrich	C.	6	108	96	13.8	Rather lean	13	4.8	R.	8	1.0	R.	3.8	2,175	2,200	2,225	4	2.56	24.74
Shale, Humansville	F. to C.	6	97	98	18.4	Plastic	14	5.6	R.	1	3.7	R.	9.3	1,700	1,900	2,100	4	2 53	10.26
RANDOLPH COUNTY—																		
Gumbo, Davy C. B. Co., Clifton	V. F.	5	380	319	2.31	Very plastic	17	8.5	V.S.	3	1.5	S.	10.0	1,600	1,750	1,900	3	1.98	......
Potters' clay, Hammetts, Huntsville	C.	7	925	118	16.7	Plastic	20	6 9	R.	1	4 0	S.	10.9	2,0 0	2,200	2,400	3	2 53	5.26
Shale, Stuart's mine, Huntsville	F. to C	6	122	99	19 3	Slightly lean	18	5 5	R.	2	6 5	R.	1 20	1,800	1,950	2,100	3	2.34	14.75
Shale, 1½ miles N. W. Huntsville	F.	6	180	168	20 8	Plastic	19	7.8	R.	4	5 8	S.	13.6	1,700	1,850	1,950	3	2.15	9.50
Shale, Moberly B., T. Co	C.	5	104	92	18 4	Slightly lean	17	5 2	R.	4	3.5	R.	8.7	1,8[illegible]0	2,050	2,250	3	2.41	9.31
Potters' clay, Larrigan shaft, Moberly	C.	8	135	122	15.8	Plastic	17	5.5	R.	1	4.5	R.	10.0	2,000	2,200	2,400	5	2.52	5.45
ST. CHARLES COUNTY—																		
Gumbo, St. Peters	V. F.	5	323	273	23.1	Very plastic	18	8 0	S.	6	1.5	V.S.	9 5	1,650	1,800	1,950	3	2.05	11.82
STE. GENEVIEVE COUNTY—																		
Shale, Sexaner farm, Ste. Genevieve	C.	6	148	117	20.0	Plastic	20	6.1	R.	2	5.6	S.	11 7	1,600	1,750	1,950	2	2.41	11.77
ST. LOUIS CITY AND COUNTY—																		
Fire clay, Christy C. Co, St. Louis	C.	8	138	114	17.0	Slightly lean	11	6.6	R.	2	4.5	S.	11.1	2,100	2,300	2,500	5	2.47	7.30
Fire clay, washed, Christy C. Co., St. Louis	C.	22	196	168	20.0	Very plastic	6	7.7	R.	5	5 1	V.S.	12.8	2,200	2,400	2,700	4	2.13	4.81
Fire clay, Jamieson, Bartold	C.	10	121	113	20	Plastic	12	7.8	R.	2	6.8	S.	14.6	2,200	2,400	2,600	4	2.40	6.86
Fire clay, washed, Jamieson, Bartold	C.	13	102	93	20	Not very p...	12	6.6	R.	5	8.4	S.	15 0	2,200	2,400	2,700	2	1.92	5 25
Fire clay, Coffin & Co, Gratiot	C.	8	257	235	19 6	Very plastic	10	8.8	S.	4	4.2	S.	13 0	2,200	2,400	2,600	3	2.44	3.84
Fire clay, washed, Coffin & Co., Gratiot	C.	4	98	91	17.3	Slightly lean	13	6.8	S.	3	6.6	S.	13.4	2,200	2,400	2,600	3	1 99	4.97
Fire clay, Sattler, St. Louis	F.	4	108	79	18.9	"	10	7.5	S.	3	5.3	R.	12.8	2,100	2,300	2,500	3	2.40	6 28
Fire clay, washed, Sattler, St. Louis	F.	8	166	120	.....	Very plastic	5	8 7	S.	2	7.3	S.	16.0	2,200	2,400	2,700	....	.....	5.12
Fire clay, Parker Russell, St. Louis	V. C.	4	146	129	14.2	Plastic	6	6.6	R.	2	4 0	R.	10 6	2,250	2,450	2,700	4	2.44	5.14

PHYSICAL TESTS ON THE MISSOURI CLAYS—Continued.

LOCALITY.	Size of grain	Tensile strength.			Per cent of water used for paste	Plasticity, by feel	Shrinkage—per cent.							Vitrified at (degrees F.)			No. samples	Specific gravity	Per cent of impurities
		No. samples tested	Maximum	Average			No. samples	In drying	Speed	No. samples	In burning	Speed	Total shrinkage	Incipient	Complete	Viscous			
ST. LOUIS CITY AND COUNTY—*Con.*																			
Fire clay, Evens & Howard, St. Louis	C.	4	91	78	15.0	Lean	13	6.3	R.	2	5.4	R	11.7	2,250	2,450	2,650	3	2 41	5.76
Fire clay, Laclede mine, St. Louis	C.	4	82	73	14.4	Lean	12	5.9	R.	3	5.3	R.	11.2	2,250	2,450	2,650	3	2.45	6.30
Pipe clay, Laclede mine, St. Louis	F	10	250	206	21.6	Very plastic	6	7.7	.....	4	2.5	......	15.2	1,800	1,950	2,150	3	2.05	13.92
Shale, Laclede mine, St. Louis	C.	14	130	107	20.0	Semi-plastic.	13	6.0	R.	3	6.5	R.	12 5	1,800	2,000	2,200	4	2.32	13 90
Shale, Prospect Hill, St Louis	C.	5	179	177	20 0	Plastic	16	5.3	R.	3	8.3	R.	13.6	1,700	1,900	2,100	....	....	13.93
Shale, Barrett	C.	....	....	...	22.0	"	12	6.0	R.	1	3.4	R.	9 4	1,925	1,950	2,000	....	.....	18.97
Brick clay, Hyd. P. B. Co., St. Louis.	C.	4	205	173	17.1	"	16	5 3	S.	1	5 5	R.	10.8	1,800	1,950	2,050	3	1.98	9.90
Potters' clay, Renneberg, Allenton	C.	7	206	183	22.3	Rather plast	22	7.1	R.	3	7 2	R.	14.3	1,700	1,900	2,100	4	2.23	10.33
SALINE COUNTY—																			
Potters' clay, Orr pit, Slater	C.	5	163	137	17.1	Plastic	17	6.5	M.	2	6.3	M.	13.0	1,900	2,100	2,300	3	2.48	7.32
SCHUYLER COUNTY—																			
Potters' clay, Charlton mine, Glenwood	F.	7	236	212	21.6	Very plastic	8	8.9	S.	2	1.5	R.	10 40	1,700	1,850	2,000	3	2.13	18.08
SCOTT COUNTY—																			
Potters' clay, Anderson's, Commerce	F.	5	254	225	19.2	"	15	7.4	S.	2	4.2	R.	11.60	1,950	2,150	2,350	3	2 03	3.56
Brick clay, Benton	F.	7	190	169	19 2	Rather lean	14	5.3	M.	2	3.4	M.	8.7	1,800	2,000	2,100	....	......	......
SHANNON COUNTY—																			
Kaolin, Trusty land, Winona	V. F.	6	201	152	28.0	Rather plast.	16	9.4	R	2	9.4	R.	18.8	1,800	2,000	2,200	....	.. ..	......

SHELBY COUNTY—																		
Fire clay, Huggins pit, Lakenan	C.	6	167	144	16.7	Plastic	14	6 2	M.	2	4.2	M.	10 4	2,200	2,400	2,600	....	.....	4.35
Fire clay, Huggins pit, Lakenan	F.	10	180	161	17.5	Very plastic	17	17.5	R.	3	4.8	R.	12 3	2,000	2,200	2,500	3	2.38	2 41
STODDARD COUNTY—																		
Potters' clay, Dexter	F.	6	168	138	20.0	Plastic	16	7 8	R.	8	4.0	S.	11.8	2,000	2,250	2,600	4	2.13	3.09
Potters' clay, Dexter	F.	5	226	199	33.3	Rather plast.	16	7.6	R.	3	8 8	R.	16.4	1,700	1,950	2,150	...	.....	.....
SULLIVAN COUNTY—																		
Shale, Milan L. & C. Co	F.	5	183	171	28.8	.....	17	6.8	R.	1	2.6	R.	9.1	1,600	1,800	.....	...	.....	.....
Shale, Ry cut, at Milan	C.	7	246	237	22 0	.....	13	7.8	R.M.	1	3.3	R.	11.1	1,700	1,900	2,050	...	.....	.....
VERNON COUNTY—																		
Shale, Deerfield	F. C.	6	94	87	16.7	Plastic	16	4.1	R.	2	3.9	R.	8.0	1,800	2,000	2,150	5	2.43	10.84
Shale, Prewitt bank	F.	6	148	129	24.7	"	12	6.3	R.	2	5.7	R.	12 0	1,500	1,700	1,900	5	2.40	14.72
Shale, Osage river	F.	6	120	105	17.3	Lean	7	5.0	R.	2	1.4	R.	6.4	1,600	1,800	2,000	4	3.71	14.11
WARREN COUNTY—																		
Flint clay, Chiles bank, Pendleton	F.	7	27	24	14 8	Very lean	14	8.0	R	3	9.0	M.	12 0	2,300	2,500	2,700	5	2.42	2.06
Flint clay, Kelley pit, Truesdale	F.	8	20	18	15.2	" "	13	2.4	R.	2	8.9	S.	11.3	2,400	2,700	2,750	4	2.39	1 00
WRIGHT COUNTY—																		
Shale, Mansfield	C.	7	134	120	18.4	Rather lean.	19	5.2	M.	1	4.7	M.	9.9	1,900	2,100	2,200	...	.....	.....

COMPILED UNITED STATES ANALYSES OF CLAY.

The following compilation of analyses of domestic and foreign clays and shales is added for the purpose of study and comparison. Many of them are well-known clays with established reputations, and are very interesting and valuable for reference purposes. They have been collected from reliable sources, as most of the domestic analyses are taken from various state geological surveys, while the foreign analyses are taken from leading metallurgical and technical publications. The following table gives the source of the information.

It should be remembered that most clay analyses are made from selected or picked specimens and are rarely from an average sample; hence they are almost invariably more or less superior to the actual clay, as used direct from the clay bank. Still such analyses are of high value in giving the essential chemical characters of the clay, and though usually misleading in giving the detrimental impurities too low, they at least show how pure the best of a deposit assays:

Abbreviations of the sources from which the compiled analyses were obtained.

A. Treatise on Metallurgy, vol. III, Crookes and Rohrig, London, 1869.
B. Treatise on Metallurgy, Falls, Refractory materials, etc., London, 1861.
C. Die Feuerfesten Thone, Bischof, Leipzic, 1876.
D. Die Thonewarren Industrie, Kerl, Brannschweig, 1879.
E. Earthy and other Minerals and Mining, D. C Davies, London, 1884.
F. Brick, Tile and Terra Cotta, C. T. Daviess, Philadelphia, 1889.
G. Tables of Analyses of Clays, Crossley, Indianapolis, 1889.
H. Transactions American Institute of Mining Engineers, vol. III.
I. Transactions American Institute of Mining Engineers, vol. X.
J. Transactions American Institute of Mining Engineers, vol. XIV.
K. Mineral Industry, vol. II, for 1893, New York, 1894.
L. Clay Worker, May, 1894 (Orton), Indianapolis.
M. Clay Worker, April, 1895 (Meade), Indianapolis.
N. Clay Worker, August, 1895 (Orton), Indianapolis.
O. Brickmaker, vol. XIII, No. 8, Chicago.
P. U. S. Geological Survey, 6th Annual Report, 1884.
Q. U. S. Geological Survey, Mineral Resources for 1892.
R. U. S. Geological Survey, Mineral Resources, 1883-84.
S. U. S. Geological Survey, Mineral Resources for 1888.
T. New Jersey Geological Survey, Report on Clays, Cook, Trenton, 1878.
U. Clay Industries of New York, Ries, Albany, 1895.
V. California State Mineralogist, Ninth Report, Irelan, Sacramento, 1889.
W. Ohio Geological Survey, vol. V, Economic Geology, E. Orton Jr., Columbus, 1884.
X. Pennsylvania Geological Survey, vol. MM.
Y. Pennsylvania Geological Survey, vol. MMM.
Z. Pennsylvania Geological Survey, vol. L.
AA. Texas Geological Survey, Second Annual Report, 1890.
BB. Texas Geological Survey, Fourth Annual Report, 1892.

CC. Arkansas Geological Survey, Annual Report, vol. I, 1889.
DD. Wisconsin Geological Survey, vol. II, 1873-77.
EE. Washington Geological Survey, Second Annual Report, Tacoma.
FF. Georgia Geological Survey, Geology of Georgia Paleozoic, Spencer, 1893.
GG. Alabama Industrial and Scientific Society, Proceedings, vol. I.
HH. Iowa Geol. Sur., laboratory, G. E. Patrick.
Mo. Missouri Geological Survey Laboratory.

ANALYSES OF CLAYS OF THE UNITED STATES.

	Titanic acid, TiO_2	Silica, SiO_2	Alumina, Al_2O_3	Combined water, H_2O	Moisture, H_2O	Iron sesquioxide, Fe_2O_3	Lime, CaO	Magnesia	Potash, K_2O	Soda, Na_2O		Total impurities	Grand total	Specific gravity	Authority (see abbreviations)	Use.	Remarks.
ALABAMA—																	
Kaolin, Talladega		43.21	37.27	18.50		Tr.	0 11	0.10	0.	68		0 89	99.87		K.	White W.	
Kaolin, Jacksonville		44.60	38 92	13.35		0.78		1 03				2.71	99.58		I.		Cambrian.
China clay, Chalk bluff, Pineville		47.20	37.76	14.24		0.91	Tr.		Tr.			0 91	100.11		G G	White W	Cretaceous.
Fire clay, Choctaw county		83.30	5.12	6.60		1.60	0.46					2.06	100 06		G G	Fire B ...	Tertiary.
ARKANSAS—																	
Fire clay, Poinsett county.		61.76	22.91	8.75		3.32	0.75	0 90	0.62	0.38		5.97	99.39		C C		Tertiary.
Fire clay, Greene county		70.43	19 15	0.63	17.64	1.70	0.52	Tr.	1.	84		4.06	100.27		C C		"
Shale, Fort Smith		58.43	22.50	6.20		8 35	...	1 14	2.18	1.03	S. 1.16	13.86	100.99		O.	Vit. brick	Coal meas.
Shale, Fort Smith		59.10	23.74	7.21		8.19	0.53	1 04	2.	40		12.15	100.20		M.	"	"
CALIFORNIA—																	
China clay, Carbondale, Amador Co.		57 02	31.06	8.95		0.53			2.	32		2.85	99.88		V.		
China clay, Grass Valley, Nevada Co		47.33	38.00	11.65		1.08	0.67	0.42	0.	71		2.88	99.86		V.		
China clay, Grass Valley, Nevada Co		57.75	30.60	10.15		0.48	0 20	0.10	1.	30		2.08	100.58		V.		
China clay, Dagget, San Bernadino Co		12.54	42.97	38 40		0.68			4.	70		5.33	99.24		V.		
Potters' clay, Lincoln, Placa Co		44.82	34 54	8.37	1.27	1.86		0.96		4.74	$CaCO_3$ 3.00	10.56	99.56		R.		
Potters' clay, Lincoln, Placa Co		41.80	38.78	6.00	1.62	2.12		1.02		3.36	$CaCO_3$ 2.64	9.14	97 44		R.		
Potter' clay, Amador county		59.98	30.29	8.05		0.27	0.28		1.	02		1 57	99.89		V.		
Fire clay, Clipper mine, Lincoln		49.08	37.09	10.60		1.91	0.53	...				2.44	99.21		V.		

ANALYSES OF CLAYS OF THE UNITED STATES—Continued.

	Titanic acid, TiO_2	Silica, SiO_2	Alumina, Al_2O_3	Combined water, H_2O	Moisture, H_2O	Iron sesquioxide, Fe_2O_3	Lime, CaO	Magnesia, MgO	Potash, K_2O	Soda, Na_2O		Total impurities	Grand total	Specific gravity	Authority (see abbreviations)	Use.	Remarks.
INDIANA—																	
China clay, Huron, Lawrence Co.	0.00	40.50	36.35	22.60		0.15	. .	0.13	0.14	.....	....	0.42	99.87	....	T	White W.	
Potters' clay, Putnam Co.	......	66.18	21.15	4.19	......	5 30	0 70	0.14	0.33		SO_3 0.6	7.14	98.66	....	G	Stone W.	
Shale, Clinton	.....	43.13	40 87	9.48	......	3.44	2.01	0 97	0.02		....	6 44	99.92	....	M	Paving B.	Coal meas.
IOWA—																	
Under clay, Crill mill, Plymouth Co.	.....	67.14	19.93	5.59	2.98	2.39	0.53	0.25	0 70	0.58	....	4.47	100.11	....	HH	... .	Cretaceous.
Brick clay, Dubuque	0 72	72 68	12.03	2.50	......	4.53	1.59	1.11	2.13	1.68	1.28	12.82	100.21	...	P	Brick	Loess.
Brick clay, Indianola	......	63.31	16 57	6.89	3 76	4.06	1.11	1.10	0 96	2.20	MnO 0.49	10 53	100 36	....	HH	"	"
Brick clay, Indianola	......	72 24	12 58	3.33	1.70	4.02	1 40	0.99	1.54	2.60	....	10.55	100 40	....	HH	"	"
Shale, Mason City	......	54.64	14 62	3.74	5.65	5 69	5.16	2 90	4.77	1.12	MnO 0.76	19.50	99 06	....	HH	"	Devonian.
Brick clay, Guthrie Center	......	68 62	14.98	3.55	2 78	4.16	1.48	1.09	1.50	1.86	MnO 0.64	10.73	100 66	....	HH	....	Loess.
Shale, Des Moines	.....	60 34	24.26	1.66	.....	7.73	1 35	0 70	3.12		....	12 90	99.16	....	M	Paving B.	Coal meas.
Brick clay, Bridgewater, Adair Co.	......	77.13	10.75	2.22	1 45	2.38	2.08	0.83	0.73	0 60	....	6.62	99.17	....	HH	Brick	Alluvium.
Brick clay, Spencer, Clay Co.	......	52.42	13.04	4 06	2.67	6.24	7.98	2.24	1.41	6.67	CO_2 7.51	24 54	100.24	....	HH	....	Loess.
KANSAS—																	
Shale, Leavenworth	.....	58 45	21.96	6.51	.....	8.43	1 05	1 57	2 00		....	13.05	99.97	....	M	Paving B.	Coal meas.
KENTUCKY—																	
Kaolin, Pryorsburg, Graves Co.	......	56 40	30 00	7.93	......	....	0 40	Tr.	3.26	2 01	....	5.67	100.00	....	G	....	Coal meas.
Flint clay, Gormon, Carter Co.	......	49 75	35.16	14 03	.....	0.30	0 54	0 15	0 07		....	1.06	100 00	....	G	Fire brick	"

ANALYSES OF CLAYS OF THE UNITED STATES—Continued.

	Titanic acid, TiO_2	Silica, SiO_2	Alumina, Al_2O_3	Combined water, H_2O	Moisture, H_2O	Iron sesquioxide, Fe_2O_3	Lime, CaO	Magnesia, MgO	Potash, K_2O	Soda, Na_2O		Total impurities	Grand total	Specific gravity	Authority (see abbreviations)	Use.	Remarks.
NEW JERSEY—*Continued.*																	
Fire clay, E. F. & J. M. Roberts, S. Amboy	1.60	43.41	39 24	13.32	1.58	0.46	0.20	......	0.47	0.42	....	1.551	00.701	.72	T.	Fire brick	Creta. S Amboy bed.
Fire clay, E. F. & J. M. Roberts, S. Amboy	1.60	44.40	39.14	14.06	0.90	0.45	.....	......	0.25	.....	....	0.70	100.24	....	T.	"	Creta. S Amboy bed.
Fireclay, Wm. Clark, S. Amboy	....	72.70	17.58	4.50	1.20	1.42	Tr.	0.43	2.34	.....	....	4.00	100.07	....	T.	"	Creta. S. Amboy bed
Fire clay, Crossman C. & M. Co., Raritan R.	1.60	48.35	35.75	12.30	1.00	0.95	.....	Tr.	0.37	.....	....	1.32	100.32	1.69	T.	"	Creta. Woodbridge bed.
Fire c., washed, Geo. Such, Burt's Creek	1.20	44.40	38.34	13.50	1.10	0.86	.....	....	0.26	0.18	....	1.30	99.84	1.73	T.	"	Creta. S. Amboy bed.
Fire clay, Sayre & Fisher, Sayreville	1.20	44 20	38.66	13.55	1.00	0.74	.....	....	0.28	0.18	....	1.20	99 81	1.08	T.	"	Creta. S. Amboy bed.
Fire clay, R. N. & H. Valentine, Sand Hills	......	47.90	36.34	12.90	1.20	1.01	.....	....	0 04	0.15	....	1.20	99.54	....	T.	"	Creta. Woodbridge bed.
Fire c., Chas. A. Campbell & Co, Sand Hills.	1.50	48.40	35 94	12 10	1 10	0.96	.....	.....	......	0.08	....	1.04	100.08	....	T.	"	Creta. Woodbridge bed.
Fire clay, E. F. Roberts, Eagleswood	......	45 60	38.40	12.50	1 30	1.20	0 22	0.25	0.59	.....	.. ..	2.26	100.06	....	T.	"	Creta. Woodbridge bed.
Sewer pipe clay, Wm. H. Berry, Woodbridge	1.00	67.70	19.91	5.50	1 00	1 69	......	0.72	7.56	......	....	4.97	100.08	1.76	T.	Sewer p.	Creta. Woodbridge bed.
Pipe clay, W. H. Benton, Woodbridge	1.70	62.10	28.80	6.70	1.00	1.69	......	0.72	2.56	......	....	4.67	100.08	1.76	T.	Sewer P.	Cretaceous.
Front brick clay, Sayre & Fisher, Sayreville	1.00	56.10	27.42	6.60	2.90	2.68	......	0.18	2.71	......	....	5.57	99.57	1.87	T.	Orn. brick	"
NEW YORK—																	
Kaolin, Kreischerville, Staten Island	......	82.51	11.57	.....	......	0.63	0.29	0.78	2.	66	....	4.36	98.44	....	U.	White W.	Cretaceous.
Potters' clay, Kreischerville	......	64.26	24.76	.....	......	0.83	0 73	Tr.	2.	35	....	3.91	92.93	...	U.	Stone W.	"
Potters' clay, Little Neck, Long Island	......	62.26	17.09	......	......	0.97	0 79	......	2.	23	....	3.90	84.74	...	U.	"	
Potters' clay, Elm Point, Long Island	......	62.06	18.09	....	......	5 40	1.06	Tr.	6.	11	....	12.56	92.71	....	U.	"	
Potters' clay, Sea Cliff, Long Island	......	62.35	28.14	6.77	......	1 12	......	....	3.17	1 76	SO_3 1.09	7.14	99.40	....	U.	"	White clay

ANALYSES OF CLAYS OF THE UNITED STATES—Continued.

	Titanic acid, TiO_2	Silica, SiO_2	Alumina, Al_2O_3	Combined water, H_2O	Moisture, H_2O	Iron sesquioxide, Fe_2O_3	Lime, CaO	Magnesia, MgO	Potash, K_2O	Soda, Na_2O		Total impurities	Grand total	Specific gravity	Authority (see abbreviations)	Use.	Remarks.
OHIO—*Continued.*																	
Fire clay, New Castle	....	55.49	28.33	11.38	.....	2.46	0.26	0.08	1.37		....	4.19	99.39	....	G.	Fire brick	Coal meas.
Fire clay, New Castle	.....	50.41	24.94	9 07	.....	2.30	0 20	0.03	2 57		....	5.10	99.52	...	G.	"	
Fire clay, Port Washington	......	59.95	33.85	5 34	....	.....	2.05	0 55	......	....	....	2.60	101 74	....	G.	"	
Fire clay, Hanging Rock	....	53.84	24.93	11.50	....	2.79	0.40	1.50	1 18	0.51	....	7.38	97.65	....	N.	"	
Fire clay, Wassell F. Co., Columbus	......	60.77	25.74	9.46	.....	1.61	0.89	0.63	1.20	......	....	4.33	100.30	....	W.	"	Coal meas.
Fire clay, Island F. Co., Steubenville	1.30	61.86	24.97	8 90	1.69	1.66	0.63	0.40	0 28	Tr.	....	2.97	100.39	....	W.	"	"
Fire clay, Bottom Clay, Zanesville	0.94	58.78	26.47	9 96	1.04	1.22	0.59	0.32	0.99	Tr.	....	3.12	100 31	....	W	"	"
Fire clay, F. S. & A. Co , E. Liverpool	1.20	60.30	24.12	7 77	0.86	1 46	0.59	0 68	2.42	Tr.	....	4.96	99.40	...	W.	Saggers..	"
Potters' clay, Brammages, Roseville	0.29	69.35	19.08	5 57	0.94	1.26	0.60	0.63	2.14	0.02	....	4.65	99.86	....	G.	Stone W .	
Pipe clay, M. N. Walker, Walker Station	1.26	54.53	27.88	8.87	0.76	2 41	0.42	0.68	3.31	0.12	....	6.94	99.54	....	W.	Sewer P..	Coal meas.
Potters' clay, Allens, Roseville	0.35	63.40	23.01	8.03	0.97	1.50	0.41	0.62	1.26	Tr.	....	3.79	99.55	....	G.	Stone W .	
Pipe clay, Freeman Bros., Freeman Sta	1.35	51.12	30.10	9.93	1.05	1.94	0.62	0.53	2.74	Tr.	....	5.83	100.50	.	W.	Sewer P..	Coal meas.
Pipe clay, W. H. Evens, Waynesburg	0 16	68.89	15 89	7.07	1 03	2.86	0.59	0.66	2.23	0.29	....	6.61	99 65	....	W.	Drain P..	
Pipe clay, Toronto, Jefferson Co	.....	70.00	19.35	5.39	...	2.22	0.15	0.34	2.90	......	....	5.61	100.26	....	L.	Sewer P..	Coal meas.
Pipe clay, Toronto, Jefferson Co	.....	57.75	28 66	8.35	.....	1.94	0.15	0.24	2 53	....	....	4.88	100.64	....	L.	" ..	"
Pipe clay, Empire, Jefferson Co	....	65.90	24.20	4.80	......	2.00	0.80	0.54	2 80	.....	....	5 64	100.54	....	L.	" ..	"
Pipe clay, Croxton Run	.....	58.10	29.60	8.70	......	1.20	0.40	0.54	1.75	......	....	3.89	100.29	....	L.	" ..	"
Shale, Royal Brick Co., Canton	....	57 10	21.29	6 00	1.30	7.31	0.29	1.53	3 44	0 61	....	13.18	98.87	....	L.	Paving B.	"

Shale, Bucyrus B. & T. C. Co., Gloucester	.....	57.15	20.26	5.50	2.70	7.54	0.90	1.62	3.05	0.58	....	13.69	99.30	....	L.	"	
Shale, Waynesburg, B. & C. Co., Waynesb'g	.....	49 30	24.00	9.40	1.20	8.40	0.56	1.60	3.91	0.19	... .	14.63	98.54	...	L.	"	
Shale, Ohio T. B. Co., Darlington	.....	57.45	21.06	5 90	1.90	7.54	0.29	1 22	3.27	0.39	....	12.81	99.02	...	L.	"	
Shale, Columbus S. P. Co., Columbus	......	58 38	20 89	7.53	...	5 78	0 44	1 57	4.68	0.34	....	11.91	99 61	....	L.	Sewer P..	
Shale, Akron V. P. B. Co., Independence	....	57.40	21 20	7.75	.....	6 57	1.00	1.40	4.10	1.00	....	14.07	100 42	....	L.	Paving B.	Coal meas.
PENNSYLVANIA—																	
Kaolin, Brandywine Summit	......	46.28	36.25	13 54	....	1 64	0.19	0 32	2.	53	....	4 68	100.75	...	K.	White W.	
Kaolin, Chestnut Hill	....	67.10	20.10	5.90	.....	3 90	0.10	0 70	2.	00	.. ..	6 70	99 80	..	K.	"	
Fire clay, Climax	.....	44 00	40.44	12 80	.....	0.96	Tr.	0.17	1	38	....	2 51	100.00	...	G.	Firebrick	Coal meas.
Fire clay, Climax	.....	42.82	40 20	12.80	....	2.59	Tr.	0.35	1.	24	....	4 18	100.00	...	G	"	"
Fire clay, Climax	.....	45.28	39 50	10.70	....	1.30	0.67	0 53	2	00	....	4 52	100.00	....	G.	"	"
Fire Clay, Solomon's Run, Johnstown	1 70	46.80	37.02	12.60	0.80	0.88	.....	....	0.20	.. ..	....	1.08	100.00	...	T.	"	"
Fire clay, Mineral Point, Johnstown	1.55	45.25	38.84	12 50	0.70	0.91	.....	.....	0.35	......	....	1.26	100.10	..	T.	"	"
Fire clay, Queen's Run, Clinton	4.00	42.44	36 69	13.37	.....	2.13	0.20	0.28	0.	72	SO_3 0.82	4.14	100.65	....	X.	"	"
Fire clay, Queen's Run, Clinton	1.46	63.18	23.70	6.87	......	1.20	0 17	0 47	2.	52	SO_3 0 19	4.55	99.76	....	X.	"	"
Fire clay, Q.'s Run, Lockhaven, Clinton Co.	2.64	45.65	36.36	13.01	.....	1.19	0.08	....	1.06	0.24	....	2.57	100.23	...	G.	"	"
Fire clay, Savage Mountain, Somerset Co.	.....	53.86	35.48	8.75	.....	1.23	0.30	0.14	.....	.....	....	1 68	99.77	...	G.	"	"
Fire clay, Savage Mountain, Somerset Co.	.....	63 04	28.59	.....	.....	0.86	1.54	0.91	.....	...	....	3.21	96 84	...	G.	"	(Calcined.)
Fire clay, Q.'s Run, Lockhaven, Clinton Co.	1.25	50.80	32.28	8 54	.....	1.77	0 05	0.47	4.22	0.34	....	6 85	99.72	..	G.	"	Coal meas.
Fire clay, Woodland mine, Clearfield Co.	......	45.29	40 07	13 18	....	1.02	0.26	0.08	0.	05	....	1.46	100.00	....	G.	"	"
Fire clay, Bradford M., Woodland, C. Co	.....	45.87	38 39	13.09	......	1.87	0.10	0.05	0.	63	....	2.65	100.00	....	G.	"	"
Fire clay, Tyrone M., Woodland, Clearf'd Co.	.....	48.35	36.37	10 56	.....	2.00	0.07	0.12	2.	54	....	4.73	100.01	....	G.	"	"
Fire clay, Upper layer, Clearfield Co	2.50	42.70	37.60	13.84	.....	2 89	0.11	0 27	0.	73	....	3.50	100.14	....	X.	"	"
Fire clay, Middle layer, Clearfield Co	2.83	43.35	37.55	14 17	......	2.15	0.08	0.28	0.	24	....	2.70	100.60	....	X.	"	"
Fire clay, Lower layer, Clearfield Co	1.70	44.55	39.00	13 66	......	1.44	0.03	0.07	0.	53	....	2.07	100.98	....	X.	"	"
Fire clay, Clearfield	.....	45 45	36.13	13.73	.....	2.28	0.17	0.34	1.	29	....	4.08	99.38	....	X.	"	"
Fier clay, Renovo F. B. C. Co., Clinton Co.	4.62	32.60	53.84	5 89	. ..	1.02	1.35	0.10	0.14	0.45	....	3.06	99.81	....	G.	"	"

ANALYSES OF CLAYS OF THE UNITED STATES.

	Titanic acid, TiO_2	Silica, SiO_2	Alumina, Al_2O_3	Combined water, H_2O	Moisture, H_2O	Iron sesquioxide, Fe_2O_3	Lime, CaO	Magnesia	Potash, K_2O	Soda, Na_2O		Total impurities	Grand total	Specific gravity	Authority (see abbreviations)	Use.	Remarks.
ALABAMA—																	
Kaolin, Talladega	....	43.21	37.27	18.50	....	Tr.	0 11	0.10	0.	68	....	0 89	99.87	...	K.	White W.	
Kaolin, Jacksonville	....	44.60	38 92	13.35	....	0.78	....	1 03	....	...	....	2.71	99.58	..	I.	....	Cambrian.
China clay, Chalk bluff, Pineville	....	47.20	37.76	14.24	....	0.91	Tr.	....	Tr.	....	....	0 91	100.11	...	G G	White W	Cretaceous.
Fire clay, Choctaw county	....	83.30	5.12	6.60	....	1.60	0.46	....	....	....	....	2.06	100 06	....	G G	Fire B ...	Tertiary.
ARKANSAS—																	
Fire clay, Poinsett county	....	61.76	22.91	8.75	....	3.32	0.75	0 90	0.62	0.38	....	5.97	99.39	....	C C	....	Tertiary.
Fire clay, Greene county	....	70.43	19 15	0.63	17.64	1.70	0.52	Tr.	1.	84	....	4.06	100.27	....	C C	....	"
Shale, Fort Smith	....	58.43	22.50	6.20	....	8 35	...	1 14	2.18	1.03	S. 1.16	13.86	100.99	....	O.	Vit. brick	Coal meas.
Shale, Fort Smith	....	59.10	23.74	7.21	....	8.19	0.53	1 04	2.	40	....	12.15	100.20	....	M.	"	"
CALIFORNIA—																	
China clay, Carbondale, Amador Co.	....	57 02	31.06	8.95	....	0.53	....	....	2.	32	....	2.85	99.88	...	V.	....	
China clay, Grass Valley, Nevada Co	....	47.33	38.00	11.65	....	1.08	0.67	0.42	0.	71	....	2.88	99.86	....	V.	....	
China clay, Grass Valley, Nevada Co	....	57.75	30.60	10.15	....	0.48	0 20	0.10	1.	30	....	2.08	100.58	...	V.	....	
China clay, Dagget, San Bernadino Co	....	12.54	42.97	38 40	....	0.63	....	....	4.	70	....	5.33	99.24	....	V.	....	
Potters' clay, Lincoln, Placa Co	....	44 82	34 54	8.37	1.27	1.86	....	0.96	....	4.74	$CaCO_3$ 3.00	10.56	99 56	....	R.	....	
Potters' clay, Lincoln, Placa Co	....	41.80	38.78	6.00	1.62	2.12	....	1.02	....	3 36	$CaCO_3$ 2.64	9.14	97 44	....	R.	....	
Potter' clay, Amador county	....	59.98	30.29	8.05	....	0.27	0.28	....	1.	02	....	1 57	99.89	....	V.	....	
Fire clay, Clipper mine, Lincoln	....	49.06	37.09	10.60	....	1.91	0 53	...	....	....	....	2.44	99.21	....	V.	....	

Fire clay, Carbondale, Amador Co.	.....	48.90	38.18	8.65	.....	2.40	0 50	0.09	1.85		.....	2.99	98.72	....	V.	.....	
Terra Cotta clay, Chico, Butte Co	.....	88.70	4.50	4.46	.....	0.50	0.93	0 36	0.63		.....	2.42	100.08	....	V.	.....	
Terra Cotta clay, Iolon, Monterey Co	.....	85.07	7.85	4.35	.....	1.16	0.25	0.35	0.83		.....	2 69	99.96	....	V.	.....	
COLORADO—																	
Fire clay, Denver Fire clay Co, Golden	.....	46.88	35.42	14 10	.....	1.74	0.44	0.20	1.19		.....	3.57	99.97	....	G.	Fire brick	Cretaceous.
Fire clay, Duncan pit, Golden	.....	52.41	32.21	14.05	.....	0.66	0.20	0.06	0.61	.....	.....	1.53	100.20	...	Q.	"	"
Fire clay, Denver Fire clay Co., Golden	.....	71.81	15 09	10.14	.....	1.75	0.14	0.05	1.02		.....	2.96	100.00	....	G.	Crucibles	"
Fire clay, Morrison	.....	71.80	15.00	8.30	.....	Tr.	3 80	.....	.....	.....	.....	3.80	98.90	....	Q.	Fire brick	"
Potters' clay, Golden	.....	62.97	14.95	3.96	5.63	5 51	2.80	2.28	1.66		CO_2 0.22	12.47	99.98	....	....	.....	"
DELAWARE—																	
Kaolin, washed, Trucks & Parker, Hokessin	.....	47 20	34.10	12 35	1.35	2.49	....	0 39	1.64	0.27	.....	8.79	99.81	....	T.	White W.	From granite
Kaolin, Newcastle	.....	72.33	16.75	7.98	.....	1.29	2.00	0 07	.....	.....	.....	3.36	100.42	....	G.	"	"
GEORGIA—																	
Kaolin, Flowery Branch	1.95	41.20	38 60	16.35	0.35	1 45	0.00	0.30	0.09	0.02	.....	1.86	100.31	....	F F	.....	Paleozoic.
Residual clay, Cartersville	.....	58.63	20.47	7 06	0.20	8.58	Tr.	1.42	3.86	0.14	.....	14.00	100.36	....	F F	Paving B.	"
Brick clay, Cartersville	.....	69 18	15 43	6.61	0.22	5.83	0.00	0.71	1.83	0.15	.....	8.52	99.96	....	F F	Red brick	Alluvial.
Brick clay, Rome	1.67	67.80	13.82	7.35	0.25	5.74	0.00	0.81	2.00	0.55	.....	9.10	59 99	....	F F	"	"
ILLINOIS—																	
Fire clay, Utica, La Salle Co	1.15	56.65	26.45	9 80	2.10	2.10	.	0.30	1.10	.....	.....	3 50	99.65	....	T	Fire B....	Coal meas.
Fire clay, Winchester	0.90	69.85	17.08	6.30	1.20	3.47	....	0.28	1.10	.....	.....	4.85	100 18	...	T	"	"
Potters' clay, Pope Co	.....	46.90	31.34	12 00	8.00	0.16	....	0.10	0.79	0.16	.....	1.21	99.45	....	T	White W.	"
Brick clay, Galena	0.40	64.61	10.64	2 18	.....	3 15	5 41	3.69	2.06	1.35	.....	.....	99.99	....	P	Brick....	Loess.
Shale, brick, Galesburg	.....	68.69	17.95	.....	.....	7 25	0.76	1.47	2.83		1 05	12.31	100.00	2.31	M	Paving B.	Coal meas.
Shale, Streator	.....	61.76	18.32	7.94	.....	2.04	.....	1.45	3.49		.....	11 98	100.00	....	M	"	"
Shale, Ottawa	.....	52.26	33.47	2.74	.....	4.51	3 01	2.91	1.10		.....	11.53	100 00	....	M	"	"

ANALYSES OF CLAYS OF THE UNITED STATES—Continued.

	Titanic acid, TiO_2	Silica, SiO_2	Alumina, Al_2O_3	Combined water, H_2O	Moisture, H_2O	Iron sesquioxide, Fe_2O_3	Lime, CaO	Magnesia, MgO	Potash, K_2O	Soda, Na_2O		Total impurities	Grand total	Specific gravity	Authority (see abbreviations)	Use.	Remarks.
INDIANA—																	
China clay, Huron, Lawrence Co	0.00	40.50	36.35	22.	60	0.15	. .	0.13	0.14	......	....	0.42	99.87	....	T	White W.	
Potters' clay, Putnam Co	......	66.18	21.15	4.19	......	5 30	0 70	0.14	0.	33	SO_3 0.6	7.14	98.66	....	G	Stone W.	
Shale, Clinton	......	43.13	40 87	9.48	......	3.44	2.01	0.97	0.	02	....	6 44	99.92	....	M	Paving B.	Coal meas.
IOWA—																	
Under clay, Crill mill, Plymouth Co	......	67.14	19.93	5.59	2.98	2.39	0.55	0.25	0 70	0.58	....	4.47	100.11	....	HH	....	Cretaceous.
Brick clay, Dubuque	0 72	72 68	12.03	2.50	......	4.53	1.59	1.11	2.13	1.68	1.28	12.32	100.21	...	P	Brick	Loess.
Brick clay, Indianola	......	63.31	16 57	6.89	3 76	4.06	1.11	1.10	0 96	2.20	MnO 0.49	10.53	100 36	....	HH	"	"
Brick clay, Indianola	......	72 24	12 58	3.33	1.70	4.02	1 40	0.99	1.54	2.60	....	10.55	100 40	....	HH	"	"
Shale, Mason City	......	54.64	14 62	3.74	5.65	5 69	5.16	2 90	4.77	1.12	MnO 0.76	19.50	99 05	....	HH	"	Devonian.
Brick clay, Guthrie Center	......	68 62	14.98	3.55	2 78	4.16	1.48	1.09	1.50	1.86	MnO 0.64	10.73	100.66	....	HH	....	Loess.
Shale, Des Moines	......	60 34	24.26	1.66	......	7.73	1 35	0 70	3.	12	....	12 90	99.16	....	M	Paving B.	Coal meas.
Brick clay, Bridgewater, Adair Co	......	77.13	10.75	2.22	1 45	2.38	2 08	0.83	0.73	0 60	....	6.62	99.17	....	HH	Brick	Alluvium.
Brick clay, Spencer, Clay Co	......	52.42	13.04	4 06	2.67	6.24	7.98	2.24	1.41	6.67	CO_2 7.51	24 54	100.24	....	HH	....	Loess.
KANSAS—																	
Shale, Leavenworth	......	58 45	21.96	6 51	......	8.43	1 05	1 57	2	00	....	13.05	99.97	....	M	Paving B.	Coal meas.
KENTUCKY—																	
Kaolin, Pryorsburg, Graves Co	......	56 40	30 00	7.93	......	....	0 40	Tr.	3.26	2 01	....	5.67	100.00	....	G	....	Coal meas.
Flint clay, Gormon, Carter Co	......	49 75	35.16	14 03	......	0.30	0 54	0 15	0	07	....	1.06	100 00	....	G	Fire brick	"

Flint clay, Gorman, Carter Co	.....	68.01	24.09	3.03	.....	FeO 1.01	3.01	.....	.....	..	.....	4 02	99.15	...	G	"	"
Flint clay, Tipton, Carter Co.	.....	46 04	39.35	14.01	...	0.10	0.15	0.09	0.22	.....	.....	0.56	99.95	...	N	"	"
Flint clay, Oliver hill, Carter Co	.....	50.95	39.49	9.18	....	.....	0.30	0.28	0	31	.....	0.89	100.51	....	G	"	"
Flint clay, Carter Co	.....	46.75	38.17	14.03	....	0.29	0.57	0.12	0	07	.....	1 06	100.00	....	S	"	"
Flint clay, Greenup Co	.....	48 26	37.47	13 03	....	Tr.	0 112	Tr.	0.269	0 283	P_2O_5 0.255	0.989	100.00	....	C	"	"
Shale, Robbins	.....	70.57	15.19	..	....	7.97	0.78	0.32	1	15	.....	10.22	100.00	..	M.	Paving b	Coal meas
Shale, Butler Co	.....	51.66	15.56	13.44	....	7 68	7.27	0.82	3.	57	.....	19.32	99.98	....	M.	"	"
Shale, Madison Co	.....	63.57	21.55	4.66	....	3.98	0.39	0 53	5	47	.....	10.37	100.15	....	M.	"	Clinton.
MARYLAND—																	
Fire clay, Mount Savage	.....	48.95	35.33	13.90	...	1.44	0.34	0.07	Tr.	.....	.....	1.85	100 03	..	O.	Fire brick	Coal meas.
Fire clay, Mount Savage	.....	50.46	35.91	12.78	.....	1 51	0.13	1.02	Tr.	..	.....	1.64	100.79	....	O.	"	"
Fire clay, Mount Savage	.....	55.75	33.23	10.37	....	.....	2.06	.....	....	.....	.....	2.06	101.41	....	O.	"	"
Fire clay, Mount Savage	1.15	56.80	30.08	7.60	0.90	1 67	.....	.....	2.30	.....	.....	3.97	100.50	....	T.	"	"
MISSISSIPPI—																	
Brick clay, Vicksburg	0 52	60.69	7.95	1 33	....	3.30	8.96	4.56	1 08	1.17	CO_2 9.63	19.44	99.53	....	P.	Brick.....	Loess.
NEW JERSEY—																	
Fire clay, Metuchin	.....	61.66	26 59	10.15	.....	1.46	Tr.	.....	0.	48	.....	1.94	100 34	2.01	Mo.	Fire brick	Creta white, Raritan b.
Fire clay, Metuchin	.....	62.78	24.37	10.56	....	2.23	Tr.	.....	0	38	.....	2.61	100.32	2.03	Mo.	"	Creta. blue, Raritan b
Fire clay, Wm. H. Berry, Woodbridge	11.30	46.90	35.90	12.80	1.50	1.10	.....	....	0 28	0.16	.....	1.54	99.94	...	T.	"	Creta. Woodbridge bed.
Fire clay, W. B. Dixon, Woodbridge	1.90	59.93	26.95	9.63	0.57	1.24	....	0.07	Tr.	Tr.	.....	1.31	100.29	....	T.	"	Creta. Raritan bed.
Fire clay, Laughlin & Powers, Woodbridge	.....	71 80	18.92	6.70	0.52	0.88	.....	.....	0.48	.....	.....	1.36	99.28	1.85	T.	"	Creta. Woodbridge bed.
Fire clay, A. Hall & Son, Woodbridge	1.10	47.75	33.83	12.20	1 50	0.77	.....	0 11	0.44	.....	.....	1.32	99.70	....	T.	"	Creta. Woodbridge bed.
Fire clay, Chas. Anness & Son, Woodbridge	.....	54.90	31 66	10 50	0 60	0.74	.....	.....	1.53	.....	.....	2.27	99.93	....	T.	"	Creta. Woodbridge bed.
Fire clay, sandy, S. A. Meeker, Woodbridge	.....	67.84	21.83	5 90	0.80	1.57	0 28	0.24	2 24	.....	.....	4.33	100.70	2.06	T.	"	Creta. Woodbridge bed.
Fire clay, B. Ellison, Bonhampton	1.60	75.25	15.50	4.90	1.30	1.20	.....	.....	0.17	.....	.....	1.37	99.92	....	T.	"	Creta. Raritan bed.
F. C., Freeman & Vanderhofen, Bonhampton	1.60	47.10	36.33	13.	60	1.07	.....	.....	0.20	.....	.....	1.27	99.90	....	T.	"	Creta. Woodbridge bed.

ANALYSES OF CLAYS OF THE UNITED STATES—Continued.

	Titanic acid, TiO_2	Silica, SiO_2	Alumina, Al_2O_3	Combined water, H_2O	Moisture, H_2O	Iron sesquioxide, Fe_2O_3	Lime, CaO	Magnesia, MgO	Potash, K_2O	Soda, Na_2O		Total impurities	Grand total	Specific gravity	Authority (see abbreviations)	Use.	Remarks.
NEW JERSEY—Continued.																	
Fire clay, F. W. & I. M. Roberts, S. Amboy	1.00	44.41	38.26	14.42	1.58	0.46	0.20	...	0.47	0.42	....	1.561	99.701	.72	T.	Fire brick	Creta. S Amboy bed.
Fire clay, F. W. & I. M. Roberts, S. Amboy	1.00	44.40	39.14	14.06	0.50	0.45	....	....	0.25	....	....	0.70	100.24	....	T.	"	Creta. S Amboy bed.
Fire clay, Wm. Clark, S. Amboy		72.70	17.08	4.50	1.20	1.42	Tr.	0.42	2.36	....	....	4.00	100.07	....	T.	"	Creta. S. Amboy bed
Fire clay, Crossman C. & M. Co., [illegible]	1.00	40.45	45.75	12.40	1.00	0.96	....	Tr.	0.37	....	....	1.32	100.32	1.69	T.	"	Creta. Woodbridge bed.
Fire c., washed, [illegible], [illegible] Creek.	1.20	44.40	38.34	14.50	1.10	0.96	....	....	0.26	0.18	....	1.30	99.84	1.73	T.	"	Creta. S. Amboy bed.
Fire clay, Sayre & Fisher, Sayreville.	1.20	44.20	38.00	14.55	1.00	0.74	.....	....	0.28	0.18	....	1.20	99.81	1.08	T.	"	Creta. S. Amboy bed.
Fire clay, H. N. & H. Valentine, Sand Hills		47.50	36.46	12.90	1.20	1.01	.....	....	0.04	0.15	....	1.20	99.54	....	T.	"	Creta. Woodbridge bed.
Fire c., Chas. A. Campbell & Co., Sand Hills	1.10	45.40	38.94	12.10	1.10	0.96	....	....	.....	0.08	....	1.04	100.08	....	T.	"	Creta. Woodbridge bed.
Fire clay, F. W. Roberts, Eagleswood		45.00	38.40	12.50	1.40	1.20	0.22	0.25	0.60	.....	.. ..	2.26	100.06	....	T.	"	Creta. Woodbridge bed.
Sewer pipe clay, Wm. H. Berry, Woodbridge	1.00	67.70	19.91	5.50	1.00	1.80	...	0.72	7.56	.....	....	4.97	100.08	1.76	T.	Sewer p..	Creta. Woodbridge bed.
Pipe clay, W. H. Benton, Woodbridge	1.70	64.10	28.90	6.70	1.00	1.80	..	0.72	2.56	.....	....	4.67	100.08	1.76	T.	Sewer P..	Cretaceous.
Front brick clay, Sayre & Fisher, Sayreville	1.00	60.10	27.42	5.00	2.50	2.08	....	0.18	2.71	...	....	5.57	99.57	1.87	T.	Orn. brick	"
NEW YORK.																	
Kaolin, Kreischerville, Staten Island		64.61	11.67			0.65	0.20	0.78	2.00		....	4.36	98.44	....	U.	White W.	Cretaceous.
Pottery clay, Kreischerville		64.20	24.70			0.90	0.74	Tr	2.80		....	3.91	92.98	...	U.	Stone W.	"
Pottery clay, Little Neck, Long Island		62.20	17.00			0.97	0.70	...	2.23		....	8.90	84.74	...	U.	"	
Pottery clay, Elm Point, Long Island		68.00	18.00			6.40	1.00	Tr	6.11		....	12.56	98.71	....	U.	"	
Pottery clay, Sea Cliff, Long Island		64.00	40.11	0.77		1.12			8.17	1.70	SO_3 1.00	7.14	99.40	....	U.	"	White clay

Potters' clay, Northport, Long Island	.....	58.84	23.40	9.20	.....	1.18	....	.....	5 04	0.34	SO_3 1.03	7 59	99 03	....	U.	"	Black Clay.
Potters' clay, Northport, Long Island	.....	68.34	19.86	6 03	.....	0 90	0.35	Tr.	3.55	0.84	....	5.64	99.90	. .	U.	"	White clay.
Slip clay, Albany	....	56.75	15.47	8.87	0 37	5.73	5.78	3.32	8.25		M_2O tr.	18.08	99.54	....	Mo	Glazing.	
Slip clay, Albany	.....	62.40	10 42	8.05		5 36	9.88	4 28	0.87		SO_3 0.65	21.23	100 00	....	B B	"	
Slip clay, Albany	.....	60.59	12 46	5.82		5.99	6.84	3.28	4.39		....	20.30	99 17	....	B B	"	
Slip clay, Albany	.....	58 47	16.90	7.49		3.72	6.19	Tr.	8.85		....	18.76	101 62	...	....	"	
Terra Cotta, Elm Point, Long Island	.....	62 06	18.09	....	.....	5.40	1.05	Tr.	6.11		....	12.56	92 71	...	U.	Terra C.	
Terra Cotta, Alfred Center	0.91	53.20	23.25	6.39	. ..	10 90	1.01	0.62	2.69		SO_3 0.41 MnO 0.52	15.22	99.90	....	U.	"	
Buff brick, Canandaigua	......	46.55	12.66	0.90	. .	4 92	14 02	4.67	2.05		CO_2 14.62	25.66	100.37	....	....	Buff brick	Glacial.
Buff brick, Newfield	......	51 30	12.21	....	.....	3.32	11.63	4.73	4.33		....	24.01	88.48	....	U.	Brick.	"
Blue clay, Glens Falls	.....	48.35	11.38	....	....	4.02	15 38	3.17	6.05		....	28.62	88.30	....	U.	Terra C.	Alluvial.
Red clay, Glens Falls	....	57.46	21.15	....	.....	5.52	3 65	1.50	4.72		....	14.39	94.00	....	U.	Terra C.	"
Brick clay, East Williston	.....	69.73	16.42	.....	.....	2.58	1.66	1.69	6.27		....	11.23	97.35	....	U.	Brick.	
Brick clay, West Neck	...	61.01	19.23	.....	.....	5.43	0.96	1.98	4.60		....	12.87	93.11	....	U.	"	
Brick clay, Warwick	0.50	53.00	23 10	9.70		7.20	0.70	2.60	4.10		....	14.60	100.90	....	U.	... .	Alluvial.
Brick clay, Buffalo	....	57.36	16.20	.....	.....	4 53	5 34	3.90	6.98		....	20.77	94.33	...	U.	Brick.	Glacial.
Brick clay, Rochester	......	50.55	15 46	.....	.....	4 38	10 95	3.35	6.30		....	24 98	90.99	....	U.	"	"
Brick clay, Warners	......	45.35	12 19	8.90	...	4.41	10.99	6.38	3.26	1.14	CO_2 7.24	26.18	99.86	...	U.	Paving B.	Silurian.
Brick clay, Watertown	......	64.39	14.40	6.64		5.00	3.60	1.31	4.66		....	14.57	100.00	...	U.	Red brick	
Blue shale, Warners	......	57.79	16.15	4.50	.....	5.20	2.73	4.67	4.11	1.22	CO_2 3.44	20.40	99.88	...	U.	Paving B.	Silurian.
Shale, Angola	....	65.15	15.29	.....	.....	6.16	3.50	1.57	5.71		....	16.94	97.38	....	U.	Sewer P..	Devonian.
Shale, Howellsville	......	64.45	17.77	.....	.....	7.04	0.58	1.85	2.52	1.95	....	13.94	06.16	....	U.	Paving B.	"
OHIO—																	
Flint fire clay, Gaylord, Scioto Co.	....	44.34	40.05	14 23	.....	0.80	0 .27	Tr.	Tr.	Tr.	.. ..	1.07	99.79	....	N.	Fire brick	Coal meas.
Flint fire clay, Salineville	....	59.92	27.56	9.70	1.12	1.08	Tr.	Tr	0.67	....	....	1 70	100.00	....	N.	"	"
Flint fire clay, C. E. Holden, Mineral Point	1.68	52.52	31 84	4.68	0.69	0.67	0.50	0.19	0.59	.....	....	1 98	100.36	....	W.	"	"
Fire clay, Bartlett, Lawrence Co.	......	55 20	31.02	8.90	.....	......	0.36	.....	2.07		....	2 43	99.45	....	G.	"	

ANALYSES OF CLAYS OF THE UNITED STATES—Continued.

	Titanic acid, TiO_2	Silica, SiO_2	Alumina, Al_2O_3	Combined water, H_2O	Moisture, H_2O	Iron sesquioxide, Fe_2O_3	Lime, CaO	Magnesia, MgO	Potash, K_2O	Soda, Na_2O		Total impurities	Grand total	Specific gravity	Authority (see abbreviations)	Use.	Remarks.
OHIO—*Continued.*																	
Fire clay, New Castle	....	55.49	28.33	11.38	....	2.46	0.26	0.08	1.37		....	4.19	99.39	....	G.	Fire brick	Coal meas.
Fire clay, New Castle	....	50.41	24.94	9.07	....	2.30	0.20	0.03	2.57		....	5.10	99.52	....	G.	"	
Fire clay, Port Washington	....	59.95	33.85	5.34	....	....	2.06	0.55	....	....	....	2.60	101.74	....	G.	"	
Fire clay, Hanging Rock	....	53.84	24.93	11.50	....	2.79	0.40	1.50	1.18	0.51	....	7.38	97.65	....	N.	"	
Fire clay, Wassell F. Co., Columbus	....	60.77	25.74	9.46	....	1.61	0.89	0.63	1.20	....	....	4.33	100.30	....	W.	"	Coal meas.
Fire clay, Island F. Co., Steubenville	1.30	61.86	24.97	8.90	1.69	1.66	0.63	0.40	0.28	Tr.	....	2.97	100.89	....	W.	"	"
Fire clay, Bottom Clay, Zanesville	0.94	58.78	26.47	9.96	1.04	1.22	0.59	0.32	0.99	Tr.	....	3.12	100.31	....	W	"	"
Fire clay, F. S. & A. Co., E. Liverpool	1.20	60.30	24.12	7.77	0.86	1.46	0.59	0.69	2.42	Tr.	....	4.96	99.40	....	W.	Saggers	"
Potters' clay, Brammages, Roseville	0.29	69.35	19.08	5.57	0.94	1.26	0.60	0.63	2.14	0.02	....	4.65	99.86	....	G.	Stone W.	
Pipe clay, M. N. Walker, Walker Station	1.26	54.53	27.88	8.87	0.76	2.41	0.42	0.68	3.31	0.12	....	6.94	99.54	....	W.	Sewer P.	Coal meas.
Potters' clay, Allens, Roseville	0.35	63.40	23.01	8.03	0.97	1.50	0.41	0.62	1.26	Tr.	....	3.79	99.55	....	G.	Stone W.	
Pipe clay, Freeman Bros., Freeman Sta	1.35	51.12	30.10	9.95	1.05	1.94	0.62	0.53	2.74	Tr.	....	5.83	100.50	.	W.	Sewer P.	Coal meas.
Pipe clay, W. H. Evens, Waynesburg	0.16	68.89	15.89	7.07	1.03	2.86	0.59	0.66	2.23	0.29	....	6.61	99.65	....	W.	Drain P.	
Pipe clay, Toronto, Jefferson Co	....	70.00	19.35	5.39	...	2.22	0.15	0.84	2.90	....	....	5.61	100.26	....	L.	Sewer P.	Coal meas.
Pipe clay, Toronto, Jefferson Co	....	57.75	28.66	8.35	....	1.94	0.15	0.24	2.53	....	....	4.88	100.64	....	L.	"	"
Pipe clay, Empire, Jefferson Co	...	65.90	24.20	4.80	....	2.00	0.80	0.54	2.80	....	....	5.64	100.54	....	L.	"	"
Pipe clay, Croxton Run	....	58.10	29.60	8.70	....	1.20	0.40	0.54	1.75	....	....	8.89	100.29	....	L.	"	"
Shale, Royal Brick Co., Canton	....	57.10	21.29	6.00	1.30	7.31	0.29	1.53	8.44	0.61	....	13.18	98.87	....	L.	Paving B.	"

Shale, Bucyrus B. & T. C. Co., Gloucester	.....	57.15	20.26	5.50	2.70	7.54	0.90	1.62	3.05	0.58	....	13.69	99.30	....	L.	"	
Shale, Waynesburg, B. & C. Co., Waynesb'g	.....	49 30	24.00	9.40	1.20	8.40	0.56	1.60	3.91	0.19	....	14.63	98.54	...	L.	"	
Shale, Ohio T. B. Co., Darlington	.....	57.45	21.06	5 90	1.90	7.54	0.29	1 22	3.27	0.39	....	12.81	99.02	...	L.	"	
Shale, Columbus S. P. Co., Columbus	......	58 38	20 89	7.53	....	5 78	0 44	1 57	4.68	0.34	....	11.91	99 61	....	L.	Sewer P ..	
Shale, Akron V. P. B. Co., Independence	....	57.40	21 20	7.75	.....	6 57	1.00	1.40	4.10	1.00	....	14.07	100 42	....	L.	Paving B.	Coal meas.
PENNSYLVANIA—																	
Kaolin, Brandywine Summit	......	46.28	36.25	13 54	....	1 64	0.19	0 32	2.53		....	4 68	100.75	...	K.	White W.	
Kaolin, Chestnut Hill	....	67.10	20.10	5.90	.....	3 90	0.10	0 70	2.00		....	6 70	99 80	..	K.	"	
Fire clay, Climax	.....	44 00	40.44	12 80	.....	0.96	Tr.	0.17	1 38		....	2 51	100.00	...	G.	Firebrick	Coal meas.
Fire clay, Climax	.....	42.82	40 20	12.80	....	2.59	Tr.	0.35	1.24		....	4 18	100.00	...	G	"	"
Fire clay, Climax	.....	45.28	39 50	10.70	....	1.30	0.67	0 53	2 00		....	4 52	100.00	....	G.	"	"
Fire Clay, Solomon's Run, Johnstown	1 70	46.80	37.02	12.60	0.80	0.88	.....	....	0.20	.....	....	1.08	100.00	...	T.	"	"
Fire clay, Mineral Point, Johnstown	1.55	45.25	38.84	12 50	0.70	0.91	.....	.....	0.35	.....	....	1.26	100.10	..	T.	"	"
Fire clay, Queen's Run, Clinton	4.00	42.44	36.69	13.37	.....	2.13	0.20	0.28	0.72		SO_3 0.82	4.14	100.65	....	X.	"	"
Fire clay, Queen's Run, Clinton	1.46	63.18	23.70	6.87	.....	1.20	0 17	0 47	2.52		SO_3 0 19	4.55	99.76	....	X.	"	"
Fire clay, Q.'s Run, Lockhaven, Clinton Co.	2.64	45.65	36.36	13.01	.....	1.19	0.08	....	1.06	0.24	....	2.57	100.23	....	G.	"	"
Fire clay, Savage Mountain, Somerset Co.	.....	53.86	35.48	8.75	.....	1.23	0.30	0.14	.....	.....	....	1 68	99.77	...	G.	"	"
Fire clay, Savage Mountain, Somerset Co.	.....	63 04	28.59	.....	.....	0.86	1.54	0.91	.....	...	....	3.21	96 84	...	G.	"	" (Calcined.)
Fire clay, Q.'s Run, Lockhaven, Clinton Co.	1.25	50.80	32.28	8 54	.....	1.77	0 05	0.47	4.22	0.34	....	6 85	99.72	..	G.	"	Coal meas.
Fire clay, Woodland mine, Clearfield Co.	......	45.29	40 07	13 18	....	1.02	0.26	0.08	0.05		....	1.46	100.00	....	G.	"	"
Fire clay, Bradford M., Woodland, C. Co	.....	45.87	38 39	13.09	......	1.87	0.10	0.05	0.63		....	2.65	100.00	....	G.	"	"
Fire clay, Tyrone M., Woodland, Clearf'd Co.	.....	48.35	36.37	10 56	.....	2.00	0.07	0.12	2.54		....	4.73	100.01	....	G.	"	"
Fire clay, Upper layer, Clearfield Co	2.50	42.70	37.60	13.84	.....	2 89	0.11	0 27	0.73		....	3 50	100.14	....	X.	"	"
Fire clay, Middle layer, Clearfield Co	2.83	43.35	37.55	14.17	......	2.15	0.08	0.23	0.24		....	2.70	100.60	....	X.	"	"
Fire clay, Lower layer, Clearfield Co	1.70	44.55	39.00	13 66	......	1.44	0.03	0.07	0.53		....	2.07	100.98	....	X.	"	"
Fire clay, Clearfield	.....	45 45	36.13	13.73	.....	2.28	0.17	0.84	1.29		....	4.08	99.38	....	X.	"	"
Fier clay, Renovo F. B. C. Co., Clinton Co.	4.62	32.60	53.84	5 89	..	1.02	1.35	0.10	0.14	0.45	....	3.06	99.81	....	G.	"	"

ANALYSES OF CLAYS OF THE UNITED STATES—Continued.

	Titanic acid, TiO_2	Silica, SiO_2	Alumina, Al_2O_3	Combined water, H_2O	Moisture, H_2O	Iron sesquioxide, Fe_2O_3	Lime, CaO	Magnesia, MgO	Potash, K_2O	Soda, Na_2O		Total impurities	Grand total	Specific gravity	Authority (see abbreviations)	Use.	Remarks.
PENNSYLVANIA—*Continued.*																	
Fire clay, Woodland, Clearfield Co	1 60	52.40	31.43	9.40	1.20	1.57	....	0.32	2 01	....	....	3.90	99.93	....	T.	Fire brick	Coal meas.
Fire clay, Macauley, Clarion Co	1.02	44.61	38 01	13.63	....	1.25	0.08	0.41	1.	74	....	3.47	100.74	....	Y.	"	"
Fire clay, Sligo F. B. Wks., Sligo, Clarion Co.	0.99	56.63	28.85	11.85	....	1.26	0.26	0 08	0	69	....	2.29	100 61	....	Y.	"	"
Fire clay, Dixon Works, Arthur, Clarion Co.	....	44 25	40.81	13.90	....	....	0 43	0.15	0 28	0.50	....	1.36	100.32	....	G.	"	"
Fire clay, Cambria F. B. Co., Feigert	....	45.51	36.86	10.71	....	2 32	0.25	0.39	3.91	0.59	....	7.46	100 51	....	G.	"	"
Fire clay, Cambria F. B. Co, Feigert	....	44.88	32.00	15.61	....	3.63	0.37	0 08	1.61	0.13	....	5.82	102.31	....	G.	"	"
Fire clay, Harkison & Walker, Beneget	....	47.23	38.41	13.78	....	0.39		0.1	9		....	0.58	100.00	....	G.	"	"
Fire clay, Harkison & Walker, Beneget	....	54.37	45.15	....	....	Tr.		0.4	8		....	0 48	100 00	....	G.	"	"
Fire clay, Soissons & Co., Connellsville	....	55 28	34.17	....	....	2 21	1.37	2.11	....	....	....	5 69	95.14	....	G.	"	"
Fire clay, Soissons & Co., Connellsville	....	55.38	30 42	13 14	....	Tr.	0.52	0.32	0	22	....	1.06	100.00	....	G.	"	"
Fire clay, Union, F. C, Keystone Junction	....	50.95	34 55	14.05	....	0 07	0.16	0 10	0.	12	....	0.45	100 00	..	G.	"	"
Fire clay, Savage F. B. Co., Keystone Jct	....	54.65	30.74	14.02	....	0.08	0 19	0 13	0.	11	....	0 51	99.92	....	G.	"	"
Fire clay, Jacob creek, Connellsville	....	56.78	26.89	8.38	....	3.22	0 37	0 99	3.	92	....	8.50	100.55	....	Z.	"	Coal meas., furnace clay
Fire clay, Connellsville	....	65 37	24.87	8.97	....	0 76	0 17	0.23	0	01	....	1 17	100.38	....	Z.	"	Coal meas., forge fire clay
Fire clay, Welch, Gloniger & Co., Hunker	....	52.58	33.12	13.68	....	0.25	....	0.29	0	08	....	0.62	100.00	....	G.	"	Coal meas.
Fire clay, Brown, Neal & Orr, Kittanning	1.03	50.37	32.89	13.76	....	1.64	0.31	0 35	0.	29	....	2.59	100 64	....	Y.	"	"
Fire clay, Stewart's, Kittanning	1.01	55 96	28.42	12 69	....	1.64	0.07	0 40	0.	62	....	2.12	100.80	....	Y.	"	"
Fire clay, Reynolds, Kittanning	1 05	58 75	25.17	8.11	....	2.20	0.71	0.94	3	54	....	7.38	100 46	....	Y.	"	"

Fire clay, Barr & Radcliffe, Elk county	1.24	44.96	38.17	14.84	......	0.51	0.12	0.08	0.07		....	0.79	100.00	....	Y.	"	"
Fire clay, Glen Mayo, Colliery, Elk county	1.19	56.27	23.23	7.78	......	5.40	0.01	2.09	4.04		....	11.54	100.00	....	Y.	"	"
Fire clay, Brown & Erskine, Bellport Mills	2.15	44.22	38.15	14.68	......	0.51	0.02	0.23	0.04		....	0.80	100.00	....	Y.	"	"
Fire C., Frederick, Munroe & Co., Farrandsvile	......	45.26	37.85	13.80	......	2.03	0.08	0.02	1.26	......	Loss 0.20	3.59	100.00	...	O.	"	"
F.C., Reese, Hammond & Co., Woodland View	0.78	43.40	39.19	14.20	....	1.03	Tr.	0.18	1.13		....	2.34	99.91	....	O.	"	"
F.C., Reese, Hammond & Co., Woodland View	1.49	55.68	29.18	12.49	....	0.84	0.13	0.18	0.25		....	1.39	100.23	....	O.	"	Coal meas., nonplastic.
Fire clay, E. E. Melick, Retort	3.83	42.33	37.01	13.74	......	0.95	0.47	0.16	1.29		....	2.87	99.78	....	G.	"	Coal meas.
Fire clay, Brady's Run, West Bridgewater	.....	62.03	23.66	8.04	....	0.90	2.34	0.82	1.08	0.58	....	5.72	99.45	...	G.	"	"
TENNESSEE—																	
Potters' clay, London	45.06	30.03	10.10	.....	4.50	4.70	4.80	.....	.....	.....	.. ..	14.00	99.19	....	G.	Stone W.	
TEXAS—																	
Kaolin, Nenees county	.....	46.60	33.66	4.53	......	......	0.43	0.96	1.65		....	3.04	87.83	....	A A	....	
Kaolin, Edwards county	.....	48.41	43.17	6.05	.....	.....	0.38	0.10	1.78		....	2.26	99.89	....	A A	....	
Potters' clay, Piedmont Springs, Grimes Co	.....	58.50	18.39	8.70	.....	3.21	2.34	1.61	2.70	4.93	....	14.79	100.38	....	B B	....	Cretaceous ..
Pipe clay, Brownwood bed, Milburn	.....	57.60	19.34	7.09	1.70	6.14	1.23	2.01	2.02	2.73	....	14.13	99.86	....	B B	....	Coal meas.
Pipe clay, Silver Moon Mine, McCollouch Co	.....	55.57	22.04	7.07	1.79	7.85	0.35	1.35	1.04	1.46	....	13.55	100.02	....	B B	....	"
WASHINGTON—																	
Fireclay, Kings county	.....	57.50	34.37	4.71		1.24	0.50	1.00	0.68		....	3.42	100.00	....	EE	....	Fuses 2760° F.
Fireclay, Mackintosh bed, King Co	.....	69.71	18.39	8.94		1.44	0.35	0.15	0.19	0.83	....	2.96	100.00	...	EE	....	Fuses 2831° F.
Fireclay, Connor mines, Skagit Co	.....	49.73	32.57	12.38		1.99	0.95	1.28	0.00	1.10	....	5.32	100.00	...	EE	....	Tertiary.
Potters' clay, Bellingham Bay	1.11	44.50	35.21	15.90		1.07	0.08	0.14	0.52	1.30	....	3.11	99.83	....	EE	....	"
Potters' clay, Port Angeles	...	45.59	31.20	13.90		0.70	0.44	0.13	0.52	0.36	MnO 0.45	2.65	93.34	....	EE	....	"
Potters' clay, Green River	......	55.75	27.17	11.18		1.54	1.12	0.00	1.21	0.00	....	3.87	97.97	...	EE	....	"
WISCONSIN—																	
Kaolinized Gneiss, Grand Rapids, Wood Co	...	69.34	19.19	2.67	......	1.75	0.44	0.31	3.30	2.48	....	8.23	99.43	....	H	....	Iron granite
Kaolin, Grand Rapids, Wood Co., Powers B	......	70.25	17.68	5.61	....	2.32	0.33	1.49	1.69	0.39	....	6.22	99.76	250	H	....	"
Kaolin, Grand Rapids, Wood Co.	......	54.87	28.87	9.48	....	1.54	1.62	0.99	2.57	0.07	FeO 0.95	7.74	100.96	....	H	....	"

ANALYSES OF CLAYS OF THE UNITED STATES—Continued.

	Titanic acid, TiO_2	Silica, SiO_2	Alumina, Al_2O_3	Combined water, H_2O	Moisture, H_2O	Iron sesquioxide, Fe_2O_3	Lime, CaO	Magnesia, MgO	Potash, K_2O	Soda, Na_2O		Total impurities	Grand total	Specific gravity	Authority (see abbreviations)	Use.	Remarks.
WISCONSIN—*Continued.*																	
Kaolin, Grand Rapids, Wood Co., Centralia	....	78.83	13 43	5.45	......	0.74	0.64	0.07	0.37	0 07	CO_2 0.01	1 70	99.61	252	H	....	Iron granite
Koalin, Grand Rapids, Wood Co.	......	49.94	36.80	14.62	......	0.72	Tr.	....	0 51	0.08	....	1.31	99.67	...	H	....	"
Kaolin, Grand Rapids, Wood Co., Powers B	......	70 83	18.93	5 45	......	1.24	0.24	0.02	2.49	0.10	CO_2 0.02	4.11	99 37	2 55	H	....	"
Fireclay, Commonwealth	.....	68.96	21 62	7 55	......	1.27	Tr.	0.13	0.18	0 22	....	1.80	99 93	....	....	Firebrick	N. P. Hulst.
White brick clay, Milwaukee.	0.35	40.22	8.47	1.95	......	2 83	15.65	7.80	2.36	0.84	CO_2 18.76, FeO 0.48, C. 0.32, SO_3 0.13, P_2O_5 0 05	30.14	100.21	....	....	Pole brick	Glacial.
White brick clay, Milwaukee	0 45	48.81	7.54	7.02	......	2.83	11.83	7.05	2 60	0.92	CO_2 15.47, FeO 0.65, C. 0.38, SO_3 0.05, P_2O_5 0.13	25.79	100.46	....	....	"	"
White brick clay, Milwaukee.	......	38.22	9.75	0.95	1.85	2.84	16.23	7 54	2 16	0.65	FeO 1.16, CO_2 18.60	30.58	99.84	....	H	Mil.cr.brk	"
Red brick clay, Madison	......	75 80	11.07	1.54	2.16	8 53	1.84	0.08	1.71	0.40	FeO 0.31, CO_2 1.09	8 99	99.56	....	H	Red brick	"

Compiled List of Foreign Analyses of Clays.

	Titanic acid, TiO_2	Silica, SiO_2	Alumina, Al_2O_3	Combined water, H_2O	Moisture, H_2O	Iron sesquioxide, Fe_2O_3	Lime, CaO	Magnesia, MgO	Potash, K_2O	Soda, Na_2O		Total impurities	Grand total	Specific gravity	Authority (see abbreviations)	Use.	Remarks.
AUSTRIA—																	
Kaolin, Zettlitz, Bohemia		42.31	38.67	13.24		1.02	0.45	0.43	3 52			5.42	99.61		D.	Porcelain	Iron granite.
Kaolin, Zettlitz, Bohemia		45 96	37 97	14.21		0.83	0 20	0.44	1.00	0.65		3.12	101.26		D.	"	"
Kaolin, Freistritz, in Steiermark		50.78	33.05	10.51		1.61	1.77	Tr.	3.04			6.42	100.76		D.	"	
Kaolin, Draufrowitz, in Mähren		61 91	24.49	6.12		1.56	0 81	0.26	4.95			7.58	100 10		D.	"	
Fire clay, Göttweith, near Krems		65 60	20.75	11.00		2.00	1.65	Tr	Tr.			3.65	101.00		G.	Saggers	
Fire clay, Blausks, in Mähren		50.75	30 52	11.88		2.75	1 23	1.02	2.01			7.01	100 06		D.	Fire brick	
Fire clay, Brisau, in Mähren		58.82	22.14	11.86		2.87	0 81	0.35	3.87			7.90	100.42		D.	"	
Fire clay, Melnik, Bohemia		40.87	36 22	12.14		2.01	2 99	1.21	4.42			10.63	99.86		D.	"	
Fire clay, Keikan, Bohemia		47.15	33 35	13 50	1.40	2.20	0.22	1.06			SO_3 0.10, P_2O_5 0.06	3.64	99.84		D.	"	
Fire clay, Göttweth, upper Austria		47 30	34 92	11.15		2.74	1.72	0.39	2.36			7.21	100.58		D.	"	
Fire clay, Wildstein, Bohemia		50.03	34.41	11 46		1.06	0.33	0.18	2.78			4.35	100.25		D.	"	
Fire clay, Thenberg, Bohemia		58 39	27.94	10 00	0.49	Tr.	2.74	1.00				8.74	100.56		B.	Saggers	
Fire clay, Leoben, Steiermark		58.27	23.22	5.89		5.61	2.43	Tr.	4.12			12.16	99 54		D.	Fire brick	
Fire clay, Voitsberg, Steiermark		54.00	20.22	10.11		5.72	1.02	0.78	4 02	3.43		14.97	99.30		D.	"	
Shale, Brunn		65.73	13.29	0.30		4.43	9 82	0 72	5.	61		20.58	99.90		M.	Paving b.	Coal meas.
BELGIUM—																	
Pot clay, Ardenne		49.64	34.78	12.00		1.80	0.68	0.41	0.41			3.30	99.72		C.	Glass pots	Coal meas.

ANALYSES OF CLAYS OF THE UNITED STATES—Continued.

	Titanic acid, TiO_2	Silica, SiO_2	Alumina, Al_2O_3	Combined water, H_2O	Moisture, H_2O	Iron sesquioxide, Fe_2O_3	Lime, CaO	Magnesia, MgO	Potash, K_2O	Soda, Na_2O		Total impurities	Grand total	Specific gravity	Authority (see abbreviations)	Use.	Remarks.
WISCONSIN—*Continued.*																	
Kaolin, Grand Rapids, Wood Co., Centralia	....	78.83	13 43	5.45	.....	0.74	0.64	0.07	0.37	0 07	CO_2 0.01	1 70	99.61	252	H	....	Iron granite
Koalin, Grand Rapids, Wood Co..	......	49.94	36.80	14 62	.....	0.72	Tr.	....	0 51	0.08	....	1.31	99.67	...	H	....	"
Kaolin, Grand Rapids, Wood Co., Powers B	......	70 83	18.93	5 45	.....	1.24	0.24	0.02	2.49	0 10	CO_2 0.02	4.11	99 37	2 55	H	....	"
Fireclay, Commonwealth	.....	68.96	21 62	7 55	.....	1.27	Tr.	0.13	0.18	0 22	....	1.80	99 93	....	....	Firebrick	N. P. Hulst.
White brick clay, Milwaukee.	0.35	40.22	8.47	1 95	.....	2 83	15.65	7.80	2.36	0.84	CO_2 18.76 FeO 0.48 C. 0.32 SO_3 0.13 P_2O_5 0 05	30.14	100.21	....	....	Pole brick	Glacial.
White brick clay, Milwaukee	0 45	48.81	7.54	7.02	.....	2.83	11.83	7.05	2 60	0.92	CO_2 15.47 FeO 0.65 C. 0.38 SO_3 0.05 P_2O_5 0.13	25.79	100.46	....	....	"	"
White brick clay, Milwaukee.	......	38.22	9.75	0.95	1.85	2.84	16.23	7 54	2 16	0.65	FeO 1.16 CO_2 18.60	30.58	99.84	....	H	Mil.cr.brk	"
Red brick clay, Madison	......	75 80	11.07	1.54	2.16	3 53	1.84	0.08	1.71	0.40	FeO 0.31 CO_2 1.09	8 99	99.56	....	H	Red brick	"

Compiled List of Foreign Analyses of Clays.

	Titanic acid, TiO_2	Silica, SiO_2	Alumina, Al_2O_3	Combined water, H_2O	Moisture, H_2O	Iron sesquioxide, Fe_2O_3	Lime, CaO	Magnesia, MgO	Potash, K_2O	Soda, Na_2O		Total impurities	Grand total	Specific gravity	Authority (see abbreviations)	Use.	Remarks.
AUSTRIA—																	
Kaolin, Zettlitz, Bohemia	....	42.31	38.67	13.24	....	1.02	0.45	0.43	3.52	....	....	5.42	99.61	....	D.	Porcelain	Iron granite.
Kaolin, Zettlitz, Bohemia	....	45.96	37.97	14.21	....	0.83	0.20	0.44	1.00	0.65	....	3.12	101.26	....	D.	"	"
Kaolin, Freistritz, in Steiermark	....	50.78	33.05	10.51	....	1.61	1.77	Tr.	3.04	....	....	6.42	100.76	....	D.	"	
Kaolin, Draufrowitz, in Mähren	....	61.91	24.49	6.12	....	1.56	0.81	0.26	4.95	....	....	7.58	100.10	....	D.	"	
Fire clay, Göttweith, near Krems	....	65.60	20.75	11.00	....	2.00	1.65	Tr	Tr.	....	....	3.65	101.00	....	G.	Saggers	
Fire clay, Blausks, in Mähren	....	50.75	30.52	11.88	....	2.75	1.23	1.02	2.01	....	....	7.01	100.06	....	D.	Fire brick	
Fire clay, Brisau, in Mähren	....	58.82	22.14	11.86	....	2.87	0.81	0.35	3.87	....	....	7.90	100.42	....	D.	"	
Fire clay, Melnik, Bohemia	....	40.87	36.22	12.14	....	2.01	2.99	1.21	4.42	....	....	10.63	99.86	....	D.	"	
Fire clay, Keikan, Bohemia	....	47.15	33.35	13.50	1.40	2.20	0.22	1.06	....	....	SO_3 0.10 P_2O_5 0.06	3.64	99.84	....	D.	"	
Fire clay, Göttweth, upper Austria	....	47.30	34.92	11.15	....	2.74	1.72	0.39	2.36	....	....	7.21	100.58	....	D.	"	
Fire clay, Wildstein, Bohemia	....	50.03	34.41	11.46	....	1.06	0.33	0.18	2.78	....	....	4.35	100.25	....	D.	"	
Fire clay, Thenberg, Bohemia	....	58.39	27.94	10.00	0.49	Tr.	2.74	1.00	....	....	....	3.74	100.56	....	B.	Saggers	
Fire clay, Leoben, Steiermark	....	58.27	23.22	5.89	....	5.61	2.43	Tr.	4.12	....	....	12.16	99.54	....	D.	Fire brick	
Fire clay, Voitsberg, Steiermark	....	54.00	20.22	10.11	....	5.72	1.02	0.78	4.02	3.43	....	14.97	99.30	....	D.	"	
Shale, Brunn	....	65.73	13.29	0.30	....	4.43	9.82	0.72	5.61		....	20.58	99.90	....	M.	Paving b.	Coal meas.
BELGIUM—																	
Pot clay, Ardenne	....	49.64	34.78	12.00	....	1.80	0.68	0.41	0.41	....	....	3.30	99.72	....	C.	Glass pots	Coal meas.

LIST OF FOREIGN ANALYSES OF CLAYS—Continued.

	Titanic acid, TiO_2	Silica, SiO_2	Alumina, Al_2O_3	Combined water, H_2O	Moisture, H_2O	Iron sesquioxide, Fe_2O_3	Lime, CaO	Magnesia, MgO	Potash, K_2O	Soda, Na_2O		Total impurities	Grand total	Specific gravity	Authority (see abbreviations)	Use.	Remarks.
GREAT BRITAIN—																	
Kaolin, Cornwall		45.82	38 60	9.08			3.47		1.	77		5.24	98 74		V.	China W.	From granite
Kaolin, St. Austell, Cornwall		47.75	38.11	12.54		0.69	0.16	0 02	0.73			1.60	100.00		B.	"	"
Kaolin, Redruth, Cornwall	0 20	66 20	24.11	7.20	0.70	0.79			0.96			1.75	100.16		T.	"	"
Kaolin, Cornwall		46.32	39.74	12 67		0.27	0.36	0.44				1.07	99.80		B.	"	"
China clay, J. Knowles & Co., Derbyshire		47.80	35.24	10.30	3.00	2.26			1.96			4.22	100.56		T.	White W.	
Pot clay, Stombridge, Worcestershire	1.00	64 10	22.22	7.10	2.18	1 92	0.14	0.18	1.10		Org. 0.58	3.00	99 60		B.	Glass P.	Coal meas.
Fire clay, Stombridge, Worcestershire		79.25	13.[illegible]7	5.11		1.38	0.08	0 42				1.88	99.81		G.	Crucibles	"
Fire clay, Stombridge, Worcestershire		45.29	35 27	16.45		2.36	0.15	0.08	0.	40		2.99	100.00		G.	C. S. pots	"
Fire clay, Stombridge, Worcestershire		73.82	15.88	6 45		2.95	Tr.	Tr.	0.	90		3.85	100.00		G.	Glass P.	"
Fire clay, Stombridge, Worcestershire	1.05	57.09	27 68	9 36	1.44	1.88		0.36	0 43			2.67	100.29		T.	"	"
Fire clay, Congreaves, Worcestershire		57.31	26.58	8.52	2.26	2 83	0.71	0 49	0.44		Org. 0 44	4.91	99.58		B.	Firebrick	"
Fire clay, Star, Glenboig, Scotland	1.10	61.45	24 68	9.00	1.90	1.67		0 10	0 20			1.97	100 10		T.	"	"
Fire clay, Star, Glenboig, Scotland	1.33	65.41	30.55			1.70	0 69	0 64	0	55		3.58	100.87		T.	"	"
Fire clay, Garnkirk, Scotland	0.95	45.65	35.30	13.70	2.70	1.60			0.75			2.35	100.65		T.	"	"
Fire clay, Stannington, Sheffield		48.04	34.47	11.15		3.05	0.66	0 45	1.94			6.10	99.76		B.	C. S. Cru.	"
Fire clay, Edgemount, Sheffield	Tr.	45.73	34.14	10.17	4.45	1.76	0.79	0.74	0.45		Org. 0.70 FeS_2 0.77	5.21	99.70		B.	"	"
Fire clay, Brierly Hill, Staffordshire		51 80	30.40	13	.11	4.14		0.50		Tr.		4.64	99 95		B.	Crucibles	"
Fire clay, Glass cote, near Tamworth		50.20	32.59	9.69	3.00	8.52	0.36	0 44	2.82			6.64	102 12		B.	Firebrick	"

Fire clay, Newcas'le-on-Tyne	.....	55.50	27.75	10.53	.....	2.01	0.67	0.75	2.19	0 44	....	6.06	99 8	...	B.	"	"
Fire clay, near Newcastle-on-Tyne	.....	53 50	30.92	9.60	1.70	1.98	.....	...	1.96	....	....	3.94	99 66	....	T.	"	"
Fire clay, Halifax, Yorkshire	.....	51 25	32.19	11.80	1.60	2 65	....	....	0 51	....	....	3.16	100.00	....	T.	Crucibles	"
Fire clay, Crook, Durham Co	.....	47.98	24.63	21.94	.....	2.44	0.26	1.67	0. 65		....	4 42	98.97	...	G.	Retorts ..	"
Fire clay, Leeds	.....	78.60	15.90	.....	.....	3.60	0 84	0.42	0. 29		....	5.15	99.65	...	G.	" ..	"
Fire clay, Teignmouth, Devonshire	.....	52.06	29.38	10 27	2.56	2.37	0.43	0.02	2 29	....	....	5 11	99.38	...	B.	Crucibles	Miocene.
Fire clay, Edensor, near Derby	.....	48 08	36 89	10 87	.....	2.26	0.55	Tr.	1 88	....	....	4.69	100.53	....	B.	"	Coal meas.
Fire clay, Poole, Dorsetshire	.....	48.99	32.11	9 63	2 33	2.34	0.43	0.22	....	....	....	6 30	99 86	....	B.	"	From granite
Fireclay, Dowlair, Wales	.....	67.12	21.18	4.82	1.39	1.55	0 32	0 84	2 02	....	Org. 0 90	5.93	100 44	...	B.	Fire brick	Coal meas.
Potters' clay, Brosely Green, South Hamp	0 62	64.06	2.60	5 85	.....	6.84	0.12	0.04	0.91	0 44	FeO 0 32 MnO 0.09	8.76	81 89	....	E	Enc. tile.	"
Brick clay, London	.....	49 44	31.26	1.94	.....	7.74	1.48	5.14	....	....	....	14.36	100.00	..	G.	Com. B...	
Sandy clay, London	.....	66.69	26 08	5.14	.....	1 26	0.84	Tr.	....	....	....	2.10	100.00	...	G.	"	
Mall clay, London	.....	43. 00		.....	.....	3 00	46.50	3.50	4 0		....	57.00	100 00	....	G.	Stock B...	
CHINA—																	
Kaolin, Sikang	.....	56.90	31.60	7.2	.....	0 50	0.50	0.50	3.40	.....	....	4.40	99.50	...	O.	Porcelain	
Kaolin, Sikang	.....	50.63	32.74	10.01	.....	2.64	0.50	0.45	0.01	....	....	8.22	99.89	....	O.	"	
Kaolin, Sikang	.....	50.50	33.70	11.20	.....	1 80	.....	0.80	1. 90		....	4.50	99.90	...	G	"	
FRANCE—																	
Kaolin, St. Yrieux, Limoges	.....	48.37	34.95	12.62	.....	1.26	.....	.....	2. 40		....	3.66	99.60	...	V.	China W.	From granite
Fire clay, Charkonnieres	.....	58 00	24.76	19 50	2.00	2.10	Tr.	1.25	.....	.....	....	3.35	107 61	....	D.	Crucibles	
Fire clay, Hurigny	....	41.00	32.57	10.07	2.45	7.33	2.05	2.00	.....	.....	....	11.38	97.47	....	D	Glass pot	
Fire clay, Hayange	.....	66.10	19.80	7.50	.....	6.30	.....	.....	.....	.....	....	6.30	99.70	...	D.	Fire brick	
Fire clay, Cheragny	....	65.67	15.00	10 00	2.10	4.05	2.64	1 05	.....	....	....	7.74	100.51	....	D.	Blast Fur	
Fire clay, La Bouchade, near Montlucon	.....	53.40	26 40	12.00	....	4.20	.....	.....	.....	....	....	4.20	98 00	....	G.	Glass pot	
Fire clay, Savanas	.....	58.76	25 10	12.50	.....	2.50	Tr.	2.51	Tr.	.....	....	5.01	101.37	....	G	Steel Cru.	
Fire clay, Bollene, Van cluse	1.15	53.15	28 19	10.50	3.60	2.76	.....	....	0.40	.....	....	3.16	99.75	....	T.	Fire brick	Coal meas.
Fire clay, Macon, Saone et-Loire	.....	80.70	13.10	4.30	1.20	0.60	.....	.....	0.15	.....	....	0.75	100 05	....	T.	"	"

LIST OF FOREIGN ANALYSES OF CLAYS—Continued.

	Titanic acid, TiO_2	Silica, SiO_2	Alumina, Al_2O_3	Combined water, H_2O	Moisture, H_2O	Iron sesquioxide, Fe_2O_3	Lime, CaO	Magnesia, MgO	Potash, K_2O	Soda, Na_2O		Total impurities	Grand total	Specific gravity	Authority (see abbreviations)	Use.	Remarks.
FRANCE—*Continued.*																	
Fire clay, Retournerloup, Seine-et-Marne	.....	42.00	38.96	16.96	2.27	0.65	1.04	0.17	.....	.....	....	2.01	102.20	....	B.	Saggers..	
Fire clay, Provius, Seine-et-Oise	.....	52.10	36 00	....	.....	1.80	5.00	2.00	.....	.....	....	8 80	96 90	....	B.	"	Cretaceous.
Fire clay, Malaise, Haute Vienne	.....	52 55	26.50	15 00	1.55	0 55	3.00	1.50	.....	.....	....	5.05	100.65	....	B.	"	
Fire clay, Conde, Seine-et-Oise	.....	44.10	53.00	16.48	12.87	1.91	1.34	0 70	Tr.		....	3.85	100.90	....	B.	"	
Fire clay, Boulogne, Pas de Calais	......	69.42	18.00	6 28	2.24	0.95	2.00	3.27	.....	.....	....	6.22	102 16	....	B.		
Potters' clay, Courbien	.....	49.18	20.60	12.00	...	6.00	4.00	......	......	......	loss 7.42	17.42	99 20	..	D.	Stone W..	
Potters' clay, Dion, in Allier	.....	52.00	22.00	9 63	6 96	4.00	6.00	......	.....	...	....	10.00	100.58	....	D.	"	
Potters' clay, Coulandon, in Allier	.....	57 20	16.04	15.46	....	12 00	2.15	4.52	.....	.....	loss 4.00	22 67	111.87	...	D.	"	
Potters' clay, Larnage, in Dronse	.....	56.20	23.00	.....	....	5.50	6 00	.....	......	......	loss 9 30	20.80	100.00	....	D	"	
Potters' clay, Meillonuas, Saone-et-Loire	......	48.00	22.00	....	17.22	6 00	4.30	.....	.....	.....	loss 8 53	18.83	106.05	....	D.	"	
Potters' clay, Meillonuas, Saone-et-Loire	.....	59.00	21 00	11 00	... .	5.05	3 85	... .	......	......	....	8.90	99.90	...	D.	"	
GERMANY—																	
Kaolin, Loshayn, Saxony	......	61.52	20 92	11.70	2.70	0.50	0 02	4.97	Tr.	....	....	5.49	102.33	...	D.		
Kaolin, Goeppersdorf, near Strehlen	....	69 44	21.35	7 08	....	0 61	0 28	Tr.	0.84	0 68	....	2 36	100 28	....	D.	Porcelain.	Crude.
Kaolin, Goeppersdorf, near Strehlen	...	47.36	37.67	12 82	....	0.67	0 17	Tr.	0.91	0.68	....	2.43	100.28	....	D.	"	Washed.
Kaolin, Passau, Bavaria	.....	48.21	31 02	6.01	.....	0.91	0.47	Tr.	3.42	....	....	4.80	100.04	....	D.	Crucibles	Iron granite.
Kaolin, Passau, Bavaria	......	51.02	31.11	14.23	.....	1 05	1.63	Tr.	0.80	. ...	....	3.48	99 84	....	D.	"	"
Kaolin, Passau, Bavaria	....	46.59	36.54	9 69	....	3.02	0 69	1.29	1.32	.....	....	6.31	99.18	....	D.	"	"

Kaolin, Moel, near Berlin	....	71.42	26.07	....	....	1.93	0.13	....	0.45		....	2.51	100.00	...	V.	Porcelain	Burnt.
Pot-clay, Coblentz	1.20	71 88	15.66	6 84	2.86	1.19	....	0.28	0.63	Tr.	....	2.10	100 04	....	T.	Glass pots	Cretaceous?
Pot-clay, Gruenstadt, Pfalz	....	47 33	35 05	10.51	....	2 30	0.16	1.11	3.18	....	....	6.75	99.64	....	C.	"	
Pot-clay, Vallendar, near Coblentz	....	46.97	37 95	10.02	....	0.95	0.04	0 11	3.00	....	....	4 10	99.04	....	C	"	Cretaceous?
Pot-clay, Schwarzenfeld	....	53.10	30.69	10.50	....	3.41	0.28	0.32	1.33	....	....	5 34	99.63	...	C.	"	
Fire clay, Gros-Alwerode, Hesse-Cassel	....	47.50	34 37	14.00	0.43	1.24	0.50	1.00	Tr.	Tr.	....	2.74	99.04	...	B.	Crucibles	
Fire clay, Gros-Alwerode, Hesse-Cassel	....	68.71	28 65	0.61	....	1.08	1.46	0.31	0 56	0.27	....	3.68	101.65	...	D.	"	
Fire clay, Gros-Alwerode, Hesse-Cassel	....	65 98	23 37	6.89	....	2.32	0 41	0 53	0.76	....	....	4.02	100.26	...	D.	"	
Fire clay, Gros-Alwerode, Hesse-Cassel	....	72.33	19 06	5.52	1.33	0.71	0.28	0 18	0.45	0.14	....	1.76	100.00	....	N.	"	
Fire clay, Saarau, Silesia	....	42.69	35.70	19.49	....	1 01	....	Tr.	1.11	....	....	2.12	100.00	....	D.	Fire brick	
Fire clay, Saarau, Silesia	....	50 41	32 66	11 64	...	3 23	...	0.50	1.56	....	....	5.29	100.00	...	D	"	
Fire clay, Tillendorf, Bunzlau	....	69.51	20 97	6.08	....	1.35	....	0.15	0 32	0 52	....	2.84	98 90	....	D.		
Fire clay, Mehlen, near Koenigswinter	....	77.32	15 57	5.61	....	0.86	Tr.	0.13	0 67	0.63	....	2.29	100 79	....	A.	Fire brick	Cretaceous.
Fire clay, Vallendar, near Coblentz	....	55.46	31 74	9.37	....	0 59	0.19	0 14	2 49	0.69	....	4.09	100.66	....	A.	"	"
Fire clay, Vallendar, near Coblentz	....	53.00	33.47	10 02	....	4.60	0.93	0 67	1.18	....	....	7.88	103.87	....	D.	"	"
Fire clay, Frankenthal, on Rhine	0.90	50.00	31.69	9.45	3.20	2 54	....	....	2.22	....	....	4.76	100 00	...	T.	"	"
Fire clay, Diesdorf, Rhineland	....	73.71	18.33	5.17	....	0.89	Tr.	0.10	2 12	0.24	....	3.35	100.56	....	D.		
Fire clay, Utweiler, Rhineland	....	62.82	26.01	8 61	....	0 56	Tr.	Tr.	1.30	0 86	....	2.72	100 16	....	D.	"	"
Fire clay, Mulheim, near Coblentz	....	47.76	35 36	11.72	....	2.69	0.16	0 07	1.24	....	....	4.16	99 00	....	D.	"	"
Fire clay, Mulheim, near Coblentz	....	46.74	36.00	11.81	....	2.57	8.40	0.33	1.05	....	....	4.35	98.90	...	?	"	"
Fire clay, Hillschied, Nassau	....	45 30	34.08	12 29	....	3.27	0 87	1.14	3.05	....	....	8 33	100.00	....	D.	"	"
Fire clay, Bendorf, Nassau	....	52.74	33.41	9 08	....	2.20	0.94	0.61	1.02	....	....	4.77	100.00	...	D.	"	"
Fire clay, Baumbach, Nassau	....	55.40	31.04	8 00	....	1.51	0.43	0.57	3 05	....	....	5 56	100.00	...	D.	"	"
Fire clay, Glenzhausen, Nassau	....	54.44	28.85	9.13	....	2.57	0.87	0.75	3.39	....	....	7.58	100.00	....	D.	"	"
Fire clay, Montabour, Nassau	....	61.74	27.08	7.59	....	0.67	0 15	0.29	2.03	1.03	....	4.17	100.58	....	D.	"	"
Fire clay, Ebernhan, Nassau	....	53.46	33 75	9.02	....	0.78	0 13	0.32	2.45	....	....	3.68	99.41	...	D.	"	"
Fire clay, Niederpleis, Nassau	....	58.32	28.05	8 66	....	1.89	0.72	0.75	1.39	....	....	4.75	99.78	....	D.	"	"

LIST OF FOREIGN ANALYSES OF CLAYS—Continued.

	Titanic acid, TiO_2	Silica, SiO_2	Alumina, Al_2O_3	Combined water, H_2O	Moisture, H_2O	Iron sesquioxide, Fe_2O_3	Lime, CaO	Magnesia	Potash, K_2O	Soda, Na_2O		Total impurities	Grand total	Specific gravity	Authority (see abbreviations)	Use.	Remarks.
GERMANY—*Continued.*																	
Fire clay, Seigenberg, Dusseldorf	....	75.63	14.19	4.87	....	2.25	Tr.	0.56	1.48	0.25	....	4.51	99.24	....	D.	"	"
Fire clay, Oberstuhl	....	64.10	26.60	0.53	....	4.36	0.75	1.42	1.26	1.42	....	9.21	100.50	....	D.	Crucibles	
Fire clay, Schwartzgerde	....	73.50	16.00	7.50	....	1.60	0.49	0.21	1.81	....	....	4.11	101.11	....	D.	"	
Fire clay, Schonigen, Hanover	....	59.01	24.26	10.24	....	4.04	1.32	0.72	1.20		....	7.28	100.79	....	A.	"	
Fireclay, Kipfendorf, Saxe-Coburg	....	60.40	24.09	10.60	....	3.70	0.55	0.61	0.29	0.22	....	5.37	100.46	....	A.	"	Triassic.
Fire clay, Kipfendorf, Saxe-Coburg	....	54.06	26.99	14.15	....	2.73	0.85	0.82	0.24	0.33	....	4.97	100.17	....	A.	"	"
Fire clay, Klingenberg, Bavaria	....	52.32	31.61	11.80	....	3.54	0.48	Tr.	Tr.	....	....	4.02	99.75	....	D.	Fire brick	
Fire clay, Bleshowitz, Silesia	....	67.82	20.40	6.06	....	2.98	0.34	0.61	1.20	0.59	....	5.72	100.00	....	D.	"	
Fire clay, Miro, German Poland	....	60.60	27.62	6.27	....	1.87	0.56	0.73	2.25	....	....	5.41	99.90	....	D.	"	
Potters' clay, Vallendar, by Coblentz	....	65.27	24.19	....	6.76	1.00	....	2.02	....	....	....	8.02	99.24	....	D.	Stone W.	Cretaceous.
JAPAN—																	
Kaolin, Harima	....	65.49	28.81	8.16	....	0.41	0.74	....	0.84	1.44	....	2.93	99.89	....	O.	Porcelain	
Kaolin, Yawato	....	62.41	24.78	9.81	....	2.68	0.49	....	0.54	....	....	8.71	100.69	.	O.	"	
Kaolin, Tororoishi	....	74.53	16.75	8.06	....	0.75	1.65	0.18	1.88	1.58	....	6.04	100.87	....	O.	"	
Kaolin, Tonoguchi	....	76.78	17.02	5.22	....	0.43	0.41	0.11	....	0.86	....	1.81	100.83	....	O.	"	
Kaolin, Shigaraki	....	58.42	28.37	5.25	....	1.20	1.42	....	2.53	2.65	....	7.80	99.88	....	O.	"	
Kaolin, Shiraye	....	47.74	36.66	13.64	....	0.42	0.99	....	0.24	0.21	....	1.86	99.92	....	O.	"	
Kaolin, Island Goto	....	48.85	36.89	5.90	....	0.46	0.40	0.15	6.80	0.87	....	8.68	100.32	....	O.	"	
Kaolin, Island Goto	....	48.42	37.09	6.16	....	0.50	0.45	0.01	6.43	0.83	....	8.22	99.89	....	O.	"	

CHAPTER XX.

BIBLIOGRAPHY OF CLAY AND CLAY PRODUCTS.

The following bibliography of the literature on clays and clay products has been selected with reference to such thoroughness as the average clay-worker can afford to give to the subject, and all the authors and standard works are mentioned that are usually accessible. Copious reference could have been made to the German technical periodicals which are rich in many articles of great theoretical and practical value; but it is so difficult to get access to them, whether in public or private libraries, that they have not been given.

To have made the bibliography exhaustive would have greatly increased the labor, and added but little to its value to the average reader, and it is offered as a compact, practical bibliography for the clay-worker and the student, rather than an exhaustive list for the privileged few.

As the work of the Germans and the French is very important in the clay industries, it has been necessary to cite their more important publications, so that the fountain head of much that has been extracted from them in the English publications could be consulted.

BIBLIOGRAPHY.

Alabama clays, see E. A. Smith.

American potters' journal, see periodicals.

Andsley and Barnes, Keramic art of Japan, London, 1875.

Baker, I. O., Durability of brick pavements, Indianapolis, 1891.

Barker, E. A., Pottery and porcelain of the United States, an historical review, New York, 1893.

Beckwith, Arthur, Pottery; observations on the materials and manufacture of terra cotta, stoneware, firebrick, porcelain, earthenware, brick, majolica and encaustic tiles, New York, 1872.

Bischof, C., Die feuerfesten Thone, Leipzig, 1876.

Bischof, Gustave, Chemical and physical geology, vol. II, pp. 176 to 184, the chemical origin of kaolin.

Bimms, R. W., A century of pottery in the city of Worcester, London, 1865.

Birch, S., History of ancient pottery, London, 1858.

Blake, W. P., Ceramic art at the Vienna Exposition, U. S. commissioners report, New York, 1875.

Blake, W. P., Ceramic art at the Paris exposition, U. S. Commissioners report, New York, 1878.

Blue, Archibald, Vitrified brick for pavements, third report, Ontario bureau of mines, pp. 103 to 133, Toronto, 1893.

Boecklin, W. Jr., Brick pavements, School of mines quarterly, vol. XII, p. 277, 1891.

Bowery, Emile, De la plasticite des argiles, Paris, 1866.

Brick-builder, see periodicals.

Brick-maker, see periodicals.

Brick, tile and pottery gazette, see periodicals.

Brongniart, Alex., Traite des arts ceramique, Paris, 1854.

Brongniart, Alex., Extrait et fragments d'un premier memoire sur les kaolins ou argiles a porcelaine, Comptes rendus, 1838, t. VII, p. 1085.

Brongnirart, Alex., et Malaguti, Second memoir sur les kaoline ou argile a porcelaine, Comptes rendus, 1841, t. XIII, pp. 735-754; Paris mus. hist. nat. archiv., 1841, t. II, pp. 217-256; Erdemann's journal prakt. chemie, 1844, t. XXXI, pp. 129-160; Zweite Denkschrift uber die kaoline oder Porzellanerden, uber die Natur und Ursprung derselben, Poggendorf's annalen, 1843, Bd. LX, pp. 89-129.

Burke, M. D., Brick for street pavements; an account of tests, Cincinnati, 1891.

California mining bureau, clays of California, vols. VIII, IX and XI, see Irelan and Johnson.

Canada clays, see W. E. Logan.

Chaffers, Wm., Marks and monograms on pottery, London, 1863.

Chamberlain, T. C., Geological report of Wisconsin, vol. II, pp. 235-6; also vol. I, p. 121, Color of Milwaukee brick and and analysis of the clay.

Champion, Two centuries of ceramic art in Bristol, England, London, 1873.

Chandler, C. F., Article on pottery and ceramics in Johnson's encyclopedia.

Champfleury, Bibliographie ceramique nomenclature analytique de tout les publications faites en Europe et en Orient sur les arts et l'industrie ceramique, Paris, 1881.

Chatelier, H. le, Action of heat on clay, French society of Mineralogy, 1887, Bulls. 5 and 6.

Chatelier, H. le, On the constitution of clays, Comptes rendus, 1887, t. CIV., pp. 1517 to 1520.

Chase, C. P., Brick pavements, Indianapolis, 1891.

Clay manufacturers engineer, see periodicals.

Clay record, see periodicals.

Clay-worker, see periodicals.

Collins, J. H., On the nature and origin of clays, with analyses, Mineralogical magazine, 1887, vol. VIII, p. 205.

Cook, D., Treatise on china clay.

Cook, Geo. H., Report on clays, Geological survey of New Jersey, Trenton, 1878.

Cook, R. A., Manufacture of firebrick at Mt. Savage, Md., Trans. Am. inst. mining engineers, vol, XIV, p. 698.

Cramer, Test cones for refractoriness, Thonindustrie Zeitung, 1887, p. 197.

Crookes and Rohlig, Metallurgy, vol. III, p, 559, London, 1869.

Crossley, Alfred, Tables of analyses of clay, Indianapolis, 1888.

Crossley, Alfred, Bricks and brick-making, Ottawa, Ill., 1889.

Cox, E. T., Porcelain, tile and potters' clays, Indiana geological survey 1878, pp. 154-163.

Culley, John, Paving-brick, Engineering news, March 1, 1890, pp. 201-202.

Daubree, A., Analyses of clays, Comptes rendus, t. LXXXIII, p. 421.

Daubree, A., Constitution of kaolin, Comptes rendus, t. LXVIII, p. 1135.

Davies, C. T, Brick, tiles and terra cotta, Philadelphia, 1889.

Davies, D. C., Fireclays and fireclay products of north Wales. British architect, January 21 and 28, 1877.

Davies, J. G. S., Report on stoneware, London international exposition of 1871, British reports, vol. I, pp. 305–314.

Deneanin, Auguste, Histoirie de la ceramique, Paris, 1875.

Dewey, F. P., Economics of United States clays, U. S. National museum, bulletin No. 42, p. 213, Washington, 1889.

Dobson, Edward, A rudimentary treatise on the manufacture of brick and tiles, 8th ed., London, 1886.

Dummler, K., Ziegel und Thonwaaren Industrie in der Vereingten Staaten, Berlin, 1894.

Ebelman et Salvetat, Recherches sur le composition des matieres employes dans le fabrication et dans le decoration de la porcelaine et china, Annales de chemie et physique, t. XXXI, p. 237.

Ebelman et Salvetat, Arts ceramique travaux de la commission francaise sur le industrie de nations, t. VI, Paris, 1851.

Elliot, Chas. W., Pottery and porcelain from earliest times to 1876, New York, 1878.

Fresenius, R., Chemische Untersuchung einer der wichtigsten Nassauischen Thone, Journal prakt. chemie, 1852, Bd. LVII, pp. 65-80.

Foy, Julien, Le ceramique des construction, Paris, 1883.

Garenier, Edward, Dictionaire de la ceramique, Paris, 1893.

Gasparin, P. de, Sur la constitution des argiles, Comptes rendus, 1872, t. LXXIV, p. 1180.

Georgia clays, see J. W. Spencer.

Gillmore, O. A., Lime, hydraulic cement and mortars, New York, 1872.

Hambley and Spiller, Analyses of brick clays and porcelain clays of Glasgow, Chemical gazette, 1856, pp. 100-590.

Hartman, Carl, Handbuch der Thone und Glass-Waaren Fabrication, Berlin, 1842.

Hendricks, S. E., Architects, builders and contractors' directory of America.

Hill, R. T. Clay statistics of the United States, U. S. geological survey, mineral resources, p. 474, Washington, 1891.

Hofman and Demond, Refractoriness of clays, Transactions american institute mining engineers, vol. XXIV, p. 32.

Howe, H. M., Chatelier pyrometer, Eng. and min. journal, vol. L, p. 427, 1890.

Illinois clays, see E. T. Cox.

Interstate vitrified brick and paving company, brick pavements, 120 pp., Philadelphia, 1884.

Irelan, L., Pottery, Ninth annual report of the state mineralogist of California, 1889.

Irving, R. D., Mineral resources of Wisconsin, Transactions American institute mining engineers, vol. VII, pp. 502-606.

Jaenicke, Grundriss der Keramik in Bezug auf Kunstgewerke, Stuttgart, 1877.

Jochem, P., Die Bestimmung der technische wichtigsten physikalischen Eigenschaften der Thone, wie Plasticitat, Bindevermogen, Schwunden, and Feuerfestandiskeit nach Zahlen, Chemische Centralblatt, (3), Bd. XVI, p. 605.

Jacquemart, Albert, History of the ceramic art, London, 1873.

Jacquemart, Albert, Histoire de la ceramique, Paris, 1873.

Johnson, W. D., Clays of California, Ninth annual report of state mineralogist, 1889, pp. 287-308.

Johnson's encyclopedia, see C. F. Chandler.

Karmarsch, Vortereitung des thones geschichte der Technologie, 1874, p. 503.

Kentucky clays, see R. H. Loughridge and Robert Peter.

Kerl, Bruno, Abriss der Thonwaaren industrie, Braunschweig, 1881.

Kerl, Bruno, Handbuch der gesammten Thonwaaren Industrie, Braunschweig, 1879, 744 pp.

Knapp, Kunst und Gewerbe-Blatt, 1858, p. 135.

Langenbeck, Karl, Chemistry of pottery, Easton, 1896.

Lesley, J. P., Origin and distribution of the Delaware and Chester kaolin deposits, Annual report of the geological survey of Pennsylvania, 1855, pp. 571-591.

Lilienberg, N., Fireclays and firebrick in Sweden, Transactions American institute mining engineers 1883, vol. XIII, pp. 320-330.

Logan, W. E., Clays of Canada, with analyses, Geological survey of Canada for 1863, pp. 641, 801, 802, 897, 915.

Loughridge, R. H., Clays of the Jackson purchase region of Kentucky, Kentucky geological survey, pp. 77-119, Frankfort, 1888.

Magniac, Chas., and R. H. Gorden Smith, Report on porcelain in the international exhibition of 1871, British reports, vol. I, pp. 243-278.

Mallet, J. W., Analyses of white porcelain clay from Jacksonville and Randolph counties, Alabama, American journal science (2) vol. XXIII, p. 183.

Marryat, History of pottery and porcelain, London, 1857.

Maryland clays, see G. H. Williams.

Maskell, W., Pottery and porcelain, 1874.

Maskell, W., Majolica, 1876.

McCreath, A. S., Analyses of Pennsylvania clays and firebrick, Geological survey Pennsylvania, report MM. pp. 357-279, 1879.

McCreath, A. S., Analyses of Pennsylvania fireclays, Geological survey Pennsylvania, report M3, pp. 95-97.

Meade, D. W., Paving-brick, its use and manufacture, Transactions American society civil engineers, vol. XXIV, pp. 553-580, 1893.

Meade, D. W., Manufacture of paving-brick, Indianapolis, 1895.

Mell, P. H., Southern soapstones, kaolins, and fireclays, and their uses, Transactions American institute mining engineers, vol. X, p. 322.

Meue, Ch., Fireclays, Bulletin de la societe industrielle de Mulhouse, 1893, pp. 114, 120, 145.

Meteyard, Life of Wedgewood, London, 1865.

Meteyard, Wedgewood and his works, London, 1873.

Meteyard, Art of pottery in England, London, 1865.

Mineralogical magazine, Analyses of china clays, vol. VIII, No. 33 1866.

Mineral resources of United States, see R. H. Hill.

Missouri clays, see H. A. Wheeler.

Muspratt, Sheridan, Chemistry as applied to art and manufacture, pp. 742-832, London.

Newberry, J. S., Raritan clays of New Jersey, American association for advancement of science, 1869.

New Jersey clays, see G. H. Cook.

New York clays, see H. Ries.

Nichols, G. W., Pottery and how it is made, New York, 1878.

Ohio clays, see Edward Orton, Jr.

Orton, Jr., Edwin, Clays and clay industries of Ohio, Geological survey of Ohio, vol. v, pp. 643 721, Columbus, 1884.

Orton, J., Edwin, Clays and clay industries of Ohio, Geological survey of Ohio, vol. VII, Columbus, 1893.

Otto, C., Ueber Prufrung der Thone auf ihre Feuerfestigkeit, Dingler's polytechnische journal, Bd. CLXIII, p. 193, 1862.

Owen, Hugh, Two centuries of ceramic art in Bristol, Glouchester, 1873.

Pennsylvania clays, Geological survey of Pennsylvania; also J. P. Lesley.

Periodicals devoted to the clay industries:

American potters' journal (weekly), Trenton, N. J.

Brick (monthly), Chicago.

Brickbuilder (monthly), Boston, Mass.

Brick-maker (semi-monthly), Chicago.

Brick, tile and pottery gazette, Ottawa, Ill.

Clay (quarterly), Willoughby, Ohio.

Clay manufacturers' engineer (weekly), Chicago.

Clay record (semi-monthly), Chicago.

Clay-worker (monthly), Indianapolis, Ind.

Paving and municipal engineering (monthly), Indianapolis.

Thonindustrie Zeitung, Germany.

Peters, Robert, Clays of Kentucky, Geological survey of Kentucky, vol. A, parts ii, iii, and vol. ii, fifth and sixth reports.

Platt, Franklin, Firebrick tests, Geological survey of Pennsylvania, report MM, pp. 270-279.

Platt, Franklin, Fireclays, Geological survey of Pennsylvania, report I.

Prestwich, Joseph, Chemical and physical geology, vol. I, p. 27, analyses, pp. 48-124, London.

Prime, Wm. C., Pottery and porcelain of all times and nations, pp. 531, New York, 1878.

Putnam, F. W., Ancient American art (prehistoric), 167 pp., Salem, 1877.

Raummer, V., Vorbereitung des Thones, Zeitschrift der Thonwaarindustrie, 1877, 1 to 7.

Redgrave, Gilbert R., Report on terra cotta, bricks, encaustic and other tiles to the international exhibition of 1871, British reports, vol. I, pp. 315 to 332, London.

Richter, Chemical analyses, Wagner's Jahresbericht, 1870, p. 228.

Richters, E., Ueber die Feuerfestandigkeit der Thone, Dingler's polytechnicsche journal, vol. CXCXI, pp. 59, 150, 229, 1869.

Ries, Heinrich, Clays of the United States, Mineral industry, vol. II., pp. 165-211, New York, 1893.

Ries, Heinrich, Hudson river brick clays, Tenth annual report U. S geological survey, Albany, 1891.

Ries, Heinrich, Clay industries of New York, Albany, 1895.

Roberts-Austin, W. C., Advances in pyrometry, Transactions american institute mining engineers, vol. XXIII, p. 407.

Scheurer-Kistner, Sur la fabrication des produits refractaires, Report chem. appliquee, pp. 264-272, 1863.

Schloesing, Th., Sur le constitution des argiles, Comptes rendus, t. LXXIX, pp. 376-473, 1874.

Schwartz, Feuerfestenthone, Berg- und Huttenmanische Zeitung, pp. 416, 1861.

Seger, H., Analysirte Meissner Kaoline, Dingler's polytechnicsche journal, Bd. CCVI, p. 277, 1885.

Seger, H., Refractory properties of clays, Thonindustrie Zeitung, p. 391, 1893.

Semper, Der Stil in den Kunsten, Frankfurt, 1860.

Shea, J. G., Bricks for street paving, Science, 1889, pp. 335-336.

Smith, E. A., Clays of Alabama, Alabama industrial and scientific society, vol. II, 1893.

Smock, J. C., Mining clays in New Jersey, Transactions american institute mining engineers, vol. III, p. 211, 1874.

Smock, J. C., New Jersey clays, Transactions american institute mining engineers, vol. VI, p. 177, 1879.

Spencer, J. W., Clays of Georgia, Geological survey of Georgia, 1893.

Strehle, Porzellan fabrication, p. 11.

Struthers, Jos., Le Chatelier pyrometer, School of mines quarterly, vol. XII, p. 143; Ibid. vol. XIII, p. 221.

Sweet, E. T., Milwaukee clays and bricks, American journal science, (3), vol. XXIV, p. 154, 1882.

Thonindustrie Zeitung, see periodicals.

Tomlinson, C., Plasticity and odor of clay; Dobson's Bricks and tiles, appendix 1, pp. 245-251.

Tomlinson, C., Pottery and porcelain, history of manufacture and uses, 186 pp., New York, 1864.

Treadwell, Jno. H., Manual of pottery and porcelain for Americans, 161 pp., New York, 1872.

Wagner, Rudolf, Chemical technology, manufacture of clays, p. 293.

Wallace, Jr., W. W., Brick pavements, Willoghby, Ohio, 62 pp. 1895.

Waring, J. B., Ceramic art in remote ages, London, 1874.

Westropp, H. M., Handbook of pottery and porcelain, or history from earliest period, 71 pp., London, 1880.

Wheeler, H. A., Clays of Missouri, Missouri geological survey, vol. XI, 622 pp., Jefferson City, 1896.

Wheeler, H. A., Vitrified paving-brick, 84 pp., Indianapolis, 1895.

Wheeler, H. A., Fusibility of clays, Engineering and mining journal, vol. XVII, p. 224, New York, 1894.

Wilber, F. A., Statistics of clays, U. S. geological survey, mineral resources, pp. 465-475, Washington, 1883.

Williams, G. H., Clays of Maryland, report of state worlds' fair board, Baltimore, 1893.

Wisconsin clays, see Irving and Chamberlain.

Worthen, A. H., Economic geology of Illinois, vol. I, pp. 278-453, 470, 496; vol. II, pp. 55, 303, 316; vol. III, pp. 235.

Young, Jennie J., Ceramic art, history and manufacture of pottery and porcelain, 499 pp., New York, 1878.

Ziegler, J., Etude ceramique, 348 pp. Paris, 1850.

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